CHAPTER 4

COMPUTER COMPONENTS AND CIRCUITS

INTRODUCTION

The computer's functions and operations can be very complex. However, fundamentally they are based upon simple building blocks that are repeated many times in the computer. The computer uses a binary system: it has two, and only two, states. The digital functions and operations of the computer are based upon logic algebra (Boolean algebra), which is a perfect fit for the binary (base 2) number system. Let's take these two concepts—logic algebra and binary—and apply them to the computer's number systems, logic, circuits, and data types and formats.

To maintain computers effectively, you must understand their components (number systems, logic, circuits, data types and formats, and power supplies) and how they make up a computer's functional areas. You must understand their functions in a computer and be able to determine if a computer's components are functioning properly.

This topic will refresh your knowledge of computer components. Keep in mind that the technology is ever changing, but the components are common to all computers; an AND gate works the same in a microcomputer as it does in a large mainframe. A computer performs arithmetic and logical functions on the input data, and then outputs data to the appropriate computer or device.

The logic circuits used in a computer will be based on the requirements of the computer and on what logic circuits best fulfill the requirements. Table 4-1 lists manuals and documents that provide information on circuits; integrated circuits (ICs) (linear and digital), their types, identification, methods of production, packaging, size integration, logic family, and specifications; standard cells (symbols); circuit types, operations and uses; Boolean algebra; and number systems. If you want to refresh your knowledge of any of these areas, we recommend you study the appropriate manuals and/or documents.

After completing this chapter, you should be able to:

- **Describe how number systems are used in computers**
- **Describe how Boolean algebra can be applied to computers**
- **Describe how ICs are packaged and their various integration sizes**
- **Describe the families of digital logic and differentiate between them**
- **Interpret digital logic gate waveshapes**
- **Describe digital ICs—their groups, logic gates, flip-flops, and functional uses**

- **Describe linear ICs—their families, groups, functions, and uses**
- **Describe timing circuit components and functions**
- **Describe computer data types and formats**
- **Describe power supply functions and how they work**

Table 4-1.—Sources of Information on Circuits, Symbols, Boolean Algebra, and Number Systems

NEETS Module 7	*Introduction to Solid-State Devices and Power Supplies*—circuits; ICs (digital and linear), their identification and packaging; and circuit, types, their operations and uses
NEETS Module 8	*Introduction to Amplifiers*—ICs (linear), their types and standard cells (symbols); and circuit types, their operations and uses
NEETS Module 9	*Introduction to Wave-Generation and Wave-Shaping Circuits*—ICs (linear and digital), their types and standard cells (symbols); and circuit types, their operations and uses
NEETS Module 13	*Introduction to Number Systems and Logic Circuits*—ICs (digital), their types and standard cells (symbols); circuit types, their operations and uses; Boolean algebra; and number systems
NEETS Module 14	*Introduction to Microelectronics*—ICs (linear and digital), their types, methods of production, identification, packaging, size integration, logic family, and specifications; standard cells (symbols); and circuit types, their operations and uses
NEETS Module 19	*The Technician's Handbook*—ICs (linear and digital), their types, identification, packaging, and specifications; standard cells (symbols); and circuit types, their operations and uses
ANSI/IEEE Standard 91-1984	*IEEE Standard Graphic Symbols for Logic Functions*—standard cells (symbols); and circuit types, their operations and uses
ANSI/IEEE Standard 991-1986	*IEEE Standard for Logic Circuit Diagrams,* 6—standard cells (symbols); and circuit types, their operations and uses
Military Specifications MIL-M-38510	*Microcircuits, General Specifications for*—ICs (linear and digital), their types, identification, methods of production, packaging, logic family, and specifications; and circuit types, their operations and uses
Military Standards MIL-STD-1562	*List of Standard Microcircuits*—circuits; ICs (linear and digital), their types, logic family, and specifications; and circuit types, their operations and uses

TOPIC 1—COMPUTER NUMBER SYSTEMS

Because digital logic circuits can be designed for more efficient operation using binary circuits instead of decimal circuits, the computer uses binary numbers to represent digital codes for instructions and data maintained internally. Digital computers use derivatives based on binary numbers. The two most popular derivatives used by digital computers today are

DECIMAL (BASE 10)	BINARY (BASE 2)	OCTAL (BASE 8)	HEXADECIMAL (BASE 16)
0	00000	0	0
1	00001	1	1
2	00010	2	2
3	00011	3	3
4	00100	4	4
5	00101	5	5
6	00110	6	6
7	00111	7	7
8	01000	10	8
9	01001	11	9
10	01010	12	A
11	01011	13	B
12	01100	14	C
13	01101	15	D
14	01110	16	E
15	01111	17	F
16	10000	20	10
Examples			
255	11111111	377	FF
256	100000000	400	100

Figure 4-1.—Illustration equivalences between binary, octal, hexadecimal, and decimal numbers.

the octal and hexadecimal number systems. Figure 4-1 illustrates the equivalences between binary, octal, hexadecimal, and decimal numbers.

Although the computer works well with binary numbers; typically, we humans do not. For one thing it takes too many bits to represent a number. Remember, in the binary number system, a bit is the smallest representation of a number, either 0 or 1. For that reason, the octal and hexadecimal number systems are used for functions and mechanization of the logic circuits. Octal numbers can be represented in groups of three bits and hexadecimal numbers can be represented in groups of four bits. These groupings can then be used for printouts or displays to represent the computer's internal contents rather than binary. Figure 4-2 illustrates how binary numbers can be displayed using the octal and hexadecimal representations of numbers. You will find this information very useful when performing maintenance because many of the maintenance panels and display control units rely on octal and hexadecimal displays.

The binary system is used in computers to represent machine codes used for program instruction and execution; and for computations (logical and mathematical operations).

TOPIC 2—COMPUTER LOGIC

You know the two digits of the binary number system can be represented by the state or condition of electrical or electronic devices. A binary 1 can be represented by a lamp that is lit or a switch that is on—a true condition. And the opposite, a binary 0, would be represented by the same devices in the opposite direction, the lamp is off or the switch is off—a false condition. **Boolean algebra,** the logic mathematics system used with digital equipment, takes the two logic levels, 1 and 0, and applies them to basic logic gates. Truth tables are frequently used to show the gate output for all possible combinations of the inputs. The basic logic gates, **AND, OR,** and **NOT,** are used indifferent variations and combinations to form the basic building blocks used in a computer, the **combinational** and **sequential** digital logic circuits. Later in this chapter, we discuss the different uses of these combinational and sequential logic circuits in the computer. In chapter 5, we discuss how the functional areas of the computer use the combinational and sequential logic circuits to process data.

TOPIC 3—COMPUTER CIRCUITS

The computer relies on electronic circuits throughout; from circuits that convert input power to the desired requirement to the circuits used for the functional areas. Today's computers rely heavily on the

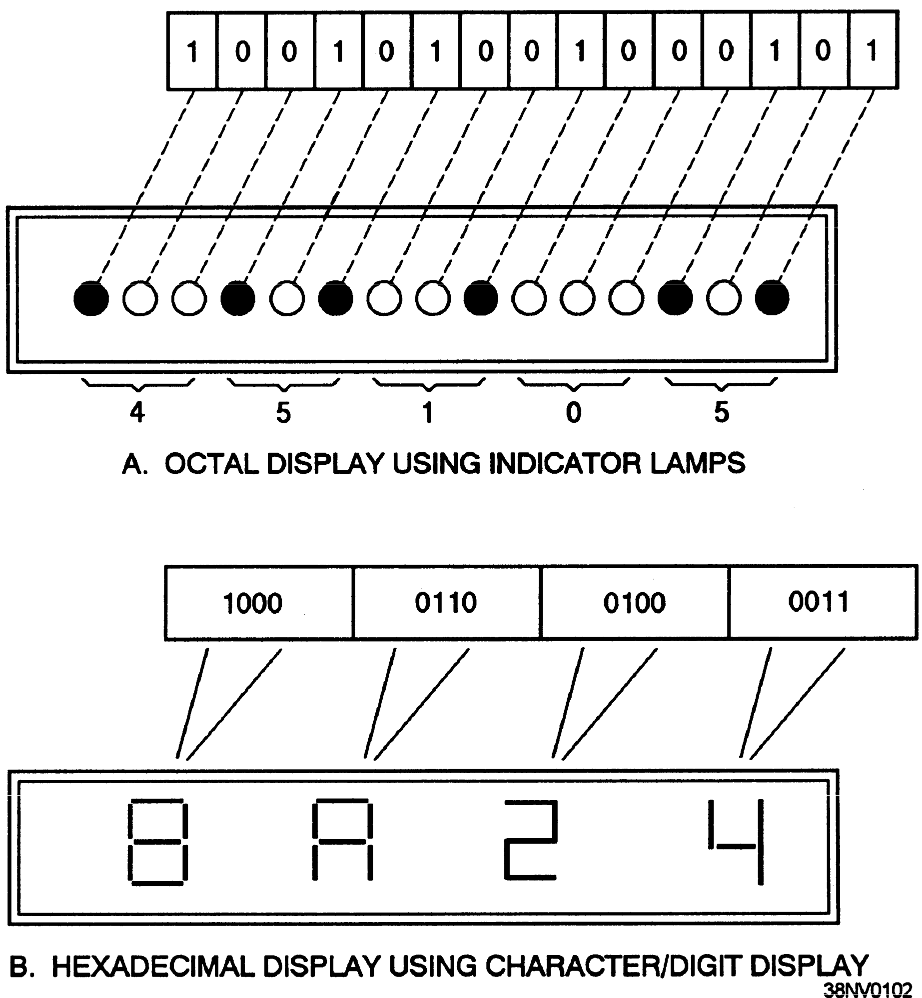


Figure 4-2.—Illustration of how binary numbers can be displayed: A. Octal display using indicator lamps; B. Hexadecimal display using character/digital display.

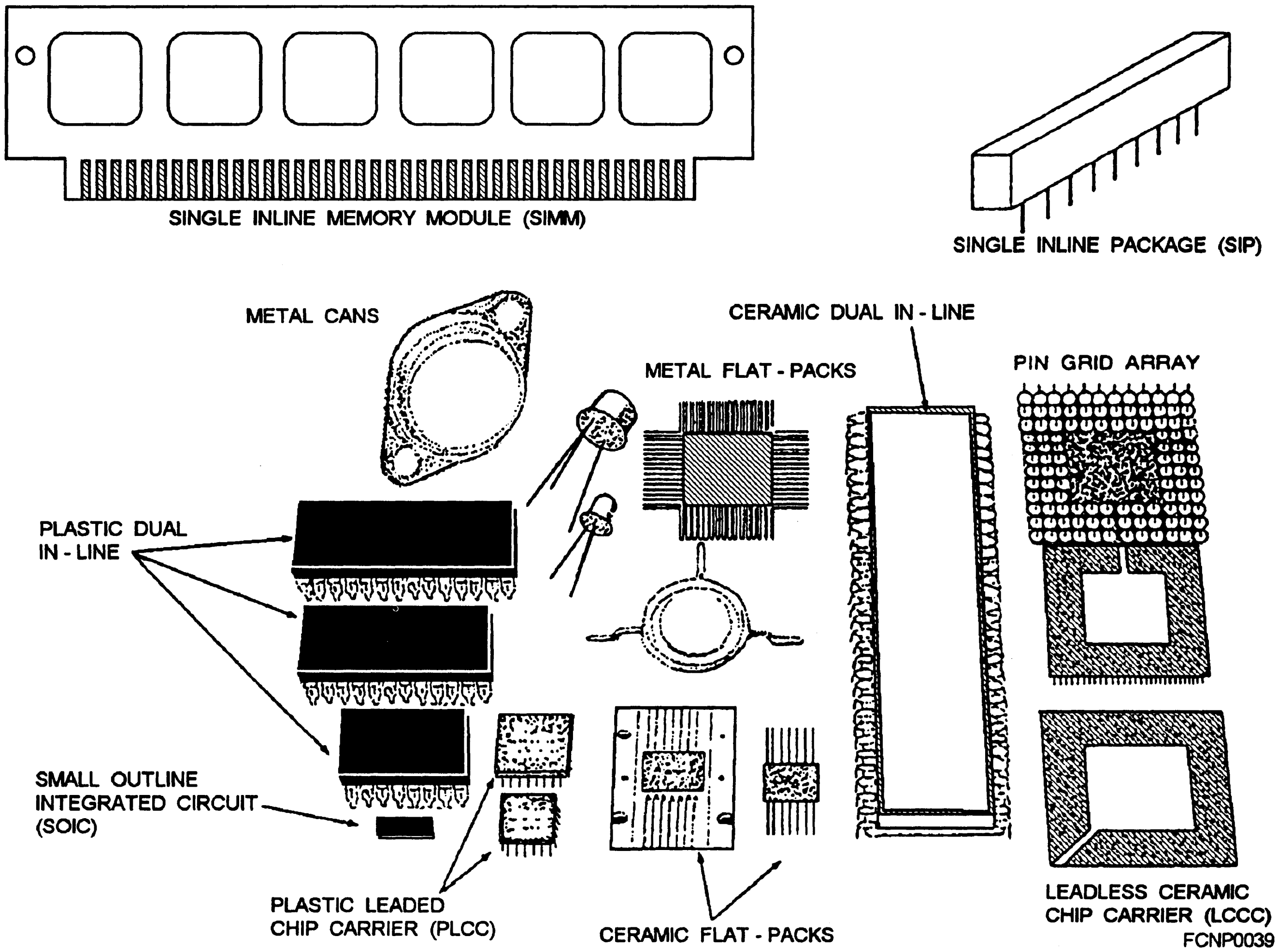


Figure 4-3.—examples of IC packaging.

use of integrated circuits. Therefore, we focus on the use of ICs in the computer.

The **integrated circuit** is a complete electronic circuit, containing transistors and perhaps diodes, resistors, capacitors, and other electronic components, along with their interconnecting electrical conductors. ICs provide three major advantages: small size, low cost, and high reliability.

IC PACKAGING

How ICs are packaged is determined by how they are integrated in a computer system. Packaging includes but is not limited to the following:

- Dual-in-line packages (DIPs); plastic and ceramic
- Flat-packs; metal and ceramic
- Metal cans (transistor-outlines [TOs])
- Leadless chip carriers (LCCs); plastic (PLCCs) and ceramic (CLCCs)
- Leaded chip carriers
- Small-outline ICs (SOICs)
- Pin grid arrays (PGAs)
- Single inline memory modules (SIMMs)
- Single inline packages (SIPS)
- Single inline pin packages (SIPPs)

See figure 4-3 for IC packaging examples.

IC SIZE INTEGRATION

The reason ICs are packaged in various sizes is not the chip they require, but the number of leads; the more leads, the larger the package. The number of gates of each IC determines the integration sizes. The types of integration are summarized as follows:

- Small-scale integration (SSI)—ICs with up to 9 gates.
- Medium-scale integration (MSI)—ICs with 10 to 100 gates.

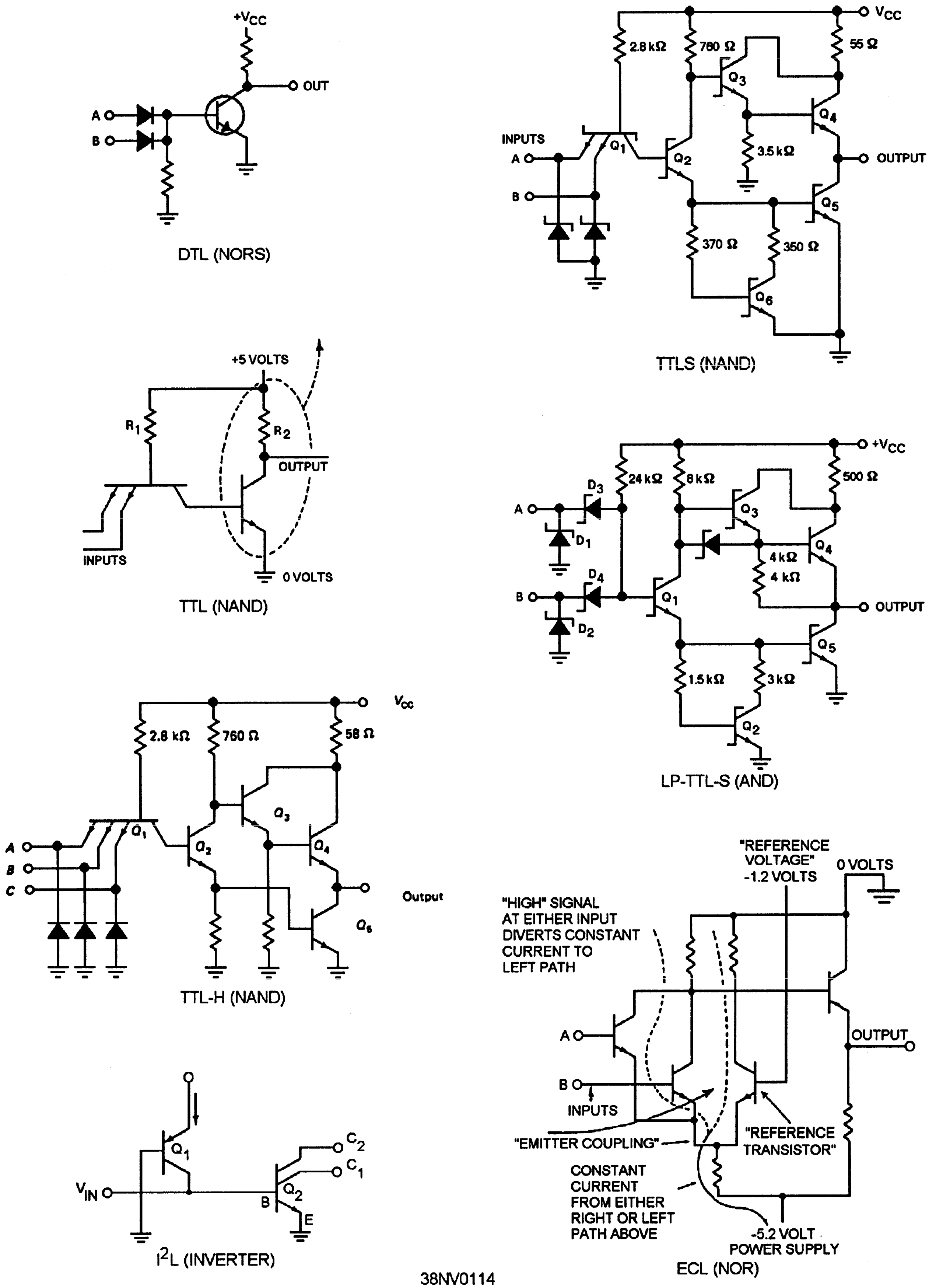


Figure 4-4.—example schematics of bipolar ICs.

- Large-scale integration (LSI)-ICs with more than 100 gates.
- Very large-scale integration (VLSI)-ICs with more than 1000 gates.

IC FAMILIES

The types of IC families are identified by the different ways in which the elements are connected and by the types of elements used (diodes, resistors, transistors, and the like). The two families of ICs in widespread use today are bipolar and metal-oxide semiconductor (MOS). They can be used in both digital and linear ICs. They can also be combined on the same IC chip to obtain the advantages from each technology. ICs that combine the technology of bipolar and MOS are referred to as Bipolar MOS (BIMOS). Refer to the glossary for a brief description of bipolar, MOS, and BIMOS if you need to.

IC CATEGORIES

To perform their functions, digital computers use two broad categories of ICs—digital and linear. **Digital ICs** contain switching-type circuitry. **Linear ICs** contain amplifying-type circuitry. You can say that the computer uses digital ICs to perform the decision-making functions internally and linear ICs to perform the regulating and sensing functions internally and externally. The digital and linear ICs rely on and work with each other. Most ICs contained in a computer are digital; hence, the computer is referred to as being digital. The larger building blocks of the computer will use these smaller building blocks that digital and linear ICs provide to perform the functions of the computer.

TOPIC 4—DIGITAL IC'S

Digital ICs handle digital information by means of switching circuits. They can also be used to control and regulate power for working devices such as a power supply. Digital ICs are used to process and store information in computers.

DIGITAL IC FAMILY TYPES

Digital IC family types include bipolar and metal-oxide semiconductors.

Bipolar ICs

Digital bipolar ICs include:

- DTL (Diode-Transistor-Logic)
- TTL (Transistor-Transistor Logic), the most widely used packaged IC. Variations of TTL include TTL-H (high-speed TTL), TTL-S (TTL-Schottky), and LP TTL-S (low-power TTL-S)
- ECL (emitter coupled logic), also called CML (current mode logic)
- IIL or I^2L (Integrated injection logic)
- Advanced Schottky (AS)
- Advanced Low-Power Schottky (ALS)

See figure 4-4 for example schematics of bipolar ICs.

Metal-Oxide-Semiconductor (MOS) ICs

Digital MOS ICs include:

- CMOS (Complementary metal-oxide semiconductor)
- NMOS (N-channel MOS)
- PMOS (P-channel MOS)
- CD (CMOS Digital)
- TTLC (Bipolar TTL series in CMOS technology)
- QMOS (Quick MOS)
- HCMOS (High-Speed CMOS)

See figure 4-5 for example schematics of MOS ICs.

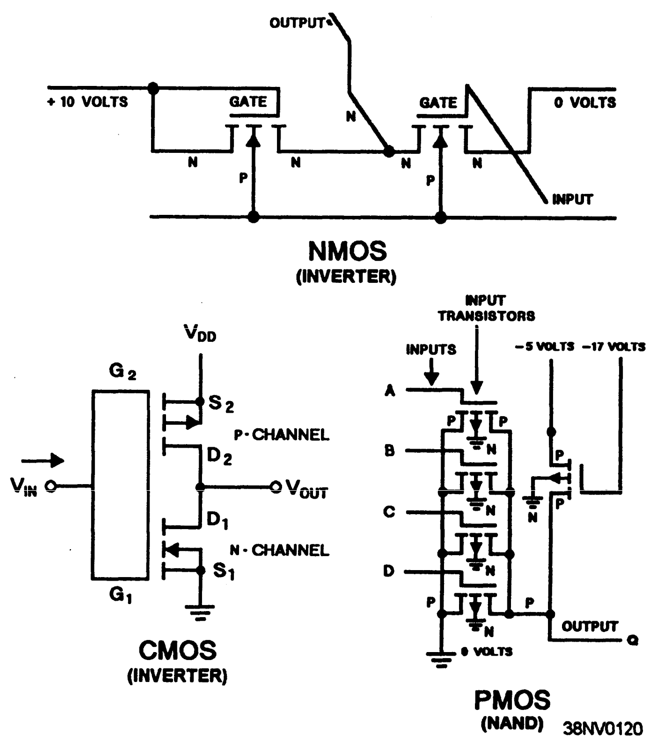


Figure 4-5.—Example schematics of MOS ICs.

DIGITAL IC CONVENTION

The theorems of Boolean algebra are applied to the AND, OR, or NOT logic gates, or any logic gates, on the basis that only two possibilities exist as far as any statement of their outputs is concerned. Their statements are either **true** or **false.** A **1** symbol is true and a **0** symbol is false. In digital logic circuits, the 1 and the 0 are represented by different voltage levels and the particular logic convention must be specific. When the logic levels for a computer are defined, the two voltages will be relative to each other when determining if it is positive or negative logic.

Digital computers can use either **positive** or **negative** logic. There are advantages and disadvantages to both types. Depending on its application in a system, the specific logic convention is consistent throughout the entire computer. The concept of positive and negative logic is more than a matter of voltage levels. Positive logic indicates that the voltage level for a 1 will be more positive than the voltage level for a 0. Negative logic indicates that the voltage level for a 1 will be more negative than the voltage level for a 0. The following examples are given:

- Positive logic: True = 1 = HIGH = +5 volts
  False = 0 = LOW = 0 volts
  OR
  True = 1 = HIGH = 0 volts
  False = 0 = LOW = –5 volts
- Negative logic: True = 1 = HIGH = 0 volts
  False = 0 = LOW = +5 volts
  OR
  True = 1 = HIGH = –5 volts
  False = 0 = LOW = 0 volts

When it is necessary to use a piece of test equipment in performing maintenance on the computer, you will need to know the logic convention the computer uses.

DIGITAL LOGIC GATE INPUT AND OUTPUT WAVESHAPES

The waveshapes of the inputs and outputs of digital logic gates are important when analyzing the operation of digital logic gates. They can provide you valuable information when you perform maintenance. **All** digital logic gates produce waveshapes on the input or the output of the gate(s). The input and the output can be monitored individually or they can be monitored at the same time. Learn what the waveshapes mean and learn how to analyze them. Remember, the clock pulses and timing signals play an important role in the operation of the digital logic gates, combinational and sequential. Waveshapes come in two types: **non-symmetrical** and **symmetrical.** Refer to figure 4-6 for examples.

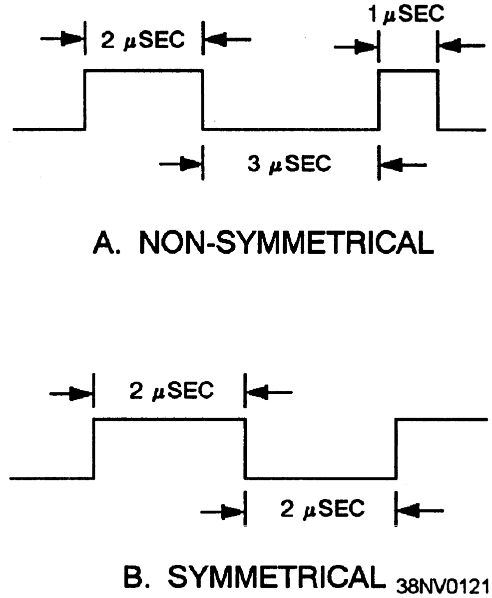


Figure 4-6.—Examples of waveshapes: A. **Non-symmetrical; B. Symmetrical.**

Three characteristics of waveshapes can play an important role in your understanding of computers. You can use them to monitor and/or analyze waveshapes. The following examples of each will help you see how they are calculated:

- Pulse width (PW) —PW is the time interval between specified reference points on the leading edge and trailing edges of the pulse waveform. Pulse widths are usually further defined as a positive PW and a negative PW. Refer to figure 4-7 for an example.

- Pulse-repetition time (PRT) —The PRT of a signal refers to the time period from the starting point of a repeating waveshape until the starting point of the next repetition. Refer to figure 4-8 for an example measurement.

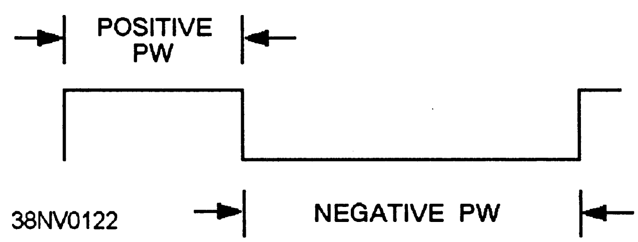


Figure 4-7.—Examples of pulse width (PW) measurements.

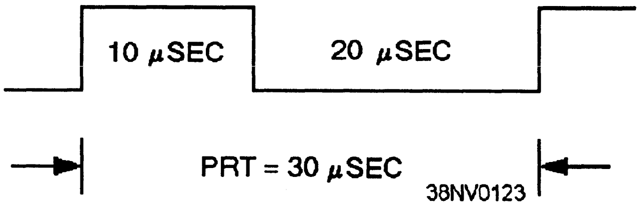


Figure 4-8.—Example of pulse-repetition time (PRT).

- Pulse-repetition frequency (PRF) —The PRF of a signal is the number times per second that a complete cycle of the signal occurs and is expressed in hertz (Hz).

Learn the relationships between PW, PRT, and PRF. They can be very helpful and can save you valuable time when you analyze waveshapes. You can apply them to non-symmetrical and symmetrical waveshapes. The basic formula is as follows: PRF = 1/PRT.

Using figure 4-8, we can calculate the PRF. Since the PRT is 30 msec, then using the formula would give: PRF = 1/PRT = 1/30 msec = 33 kHz.

DIGITAL IC GROUPS

The basic building blocks of digital logic circuits contained in a computer are **logic gates.** The logic circuits contained in digital logic circuits can be classified into two groups: **combinational** and **sequential.**

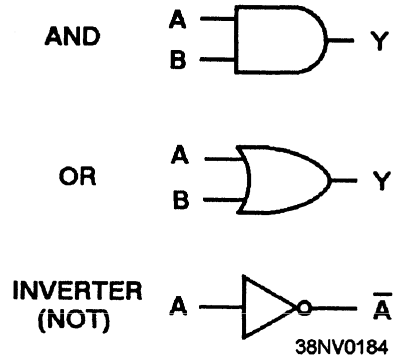
- Combinational digital logic circuits —The basic building block for combinational digital circuits is the logic gate.

- Sequential digital logic circuits —The basic building block for sequential digital circuits is the flip-flop. Flip-flops are formed from variations of the combinational digital circuits.

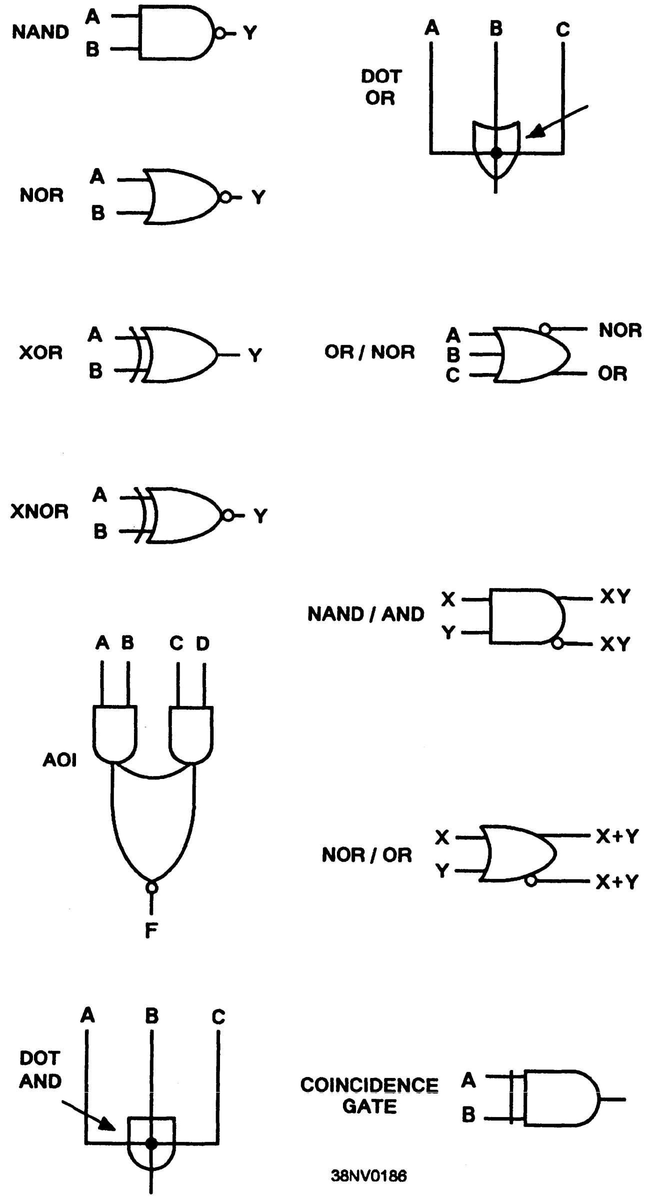
Digital Logic Gates

Digital logic gates are the basis for operations in a digital computer. The digital logic gates you will encounter operate with binary numbers; hence, the term *digital logic gates.* They are combinational and sequential logic elements.

The **AND, OR,** and **NOT** logic gates are the basis for all logic gates. These three logic gates are used in different combinations and variations to form logic gates that perform decision-making functions throughout the computer. Included in our discussion are the symbols associated with the logic gates. The basic logic gates with their symbols are as follows:



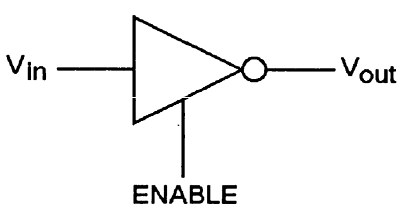
Simple variations of the three basic functions AND, OR, and NOT gates are used as building blocks for the other types of logic gates used in the computer. These logic gates with their symbols are as follows:



Another variation of the three basic functions is the **tristate logic gate.** It has three states: the standard 0 and 1 and a third state, which disengages the gate from the system. In tristate logic, the third state is an open circuit. A tristate device allows the connection of the outputs of devices in parallel without affecting circuit operation. An example of a tristate inverter and its truth table is provided in figure 4-9. When the enable signal corresponds to logic 0, the circuit operates as a normal inverter; if V_{in} is a logic 0, V_{out} is a logic 1, and vice versa. If, however, the circuit is enabled (enabled = 1), the output is an open circuit regardless of the states of the input signal.

Flip-Flops

Flip-flops are sequential logic elements. Their operation is influenced by their previous condition, or by the sequential application of clock pulses that set the timing of all computers. More about timing later in this topic. Flip-flops are also called bistable multi vibrators. The output of a flip-flop (0 or 1) remains the same until a specific input signal changes its output state. Flip-flops are used to store data temporarily, perform mathematical operations, count operations, or to receive and transfer data. They have only two distinct outputs and can have up to five different inputs depending on the type of flip-flop. They can represent one bit or more than one bit. Refer to figure 4-10 for an example of a basic flip-flop.



A. LOGIC SYMBOL

ENABLE	V_{in}	V_{out}
0	0	1
0	1	0
1	0	OPEN CIRCUIT
1	1	OPEN CIRCUIT

B. TRUTH TABLE 38NV0124

Figure 4-9.—Example of a tristate inverter: A. Logic symbol; B. Truth table.

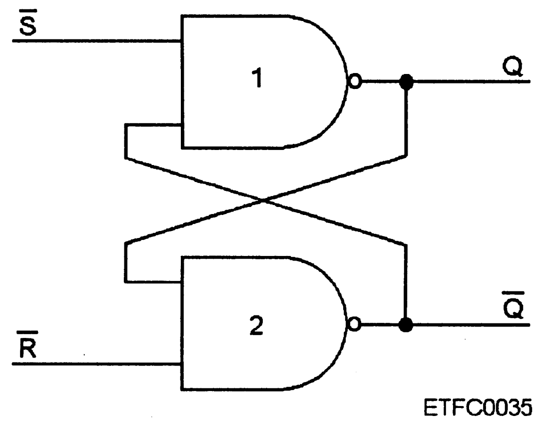


Figure 4-10.—Example of a basic flip-flop.

FLIP-FLOP CHARACTERISTICS AND TYPES.— Flip-flops share one characteristic that is consistent with the various types of flip-flops. They have two, and only two, distinct output states. Some basic terms used with flip-flops for the output labels and input labels as follows:

- The output labels are Q and $\overline{Q}$, and always complementary to each other. When Q = 1, then $\overline{Q}$ = = 0; and vice versa.
- The input labels are R= reset; S = set; T= toggle; CLK = clock; PS = preset; CLR = clear; and J, K, or D = data.

The four types of flip-flops (fig. 4-11) are as follows:

- R-S (Reset-Set) flip-flop —Temporarily holds or stores information until it is needed

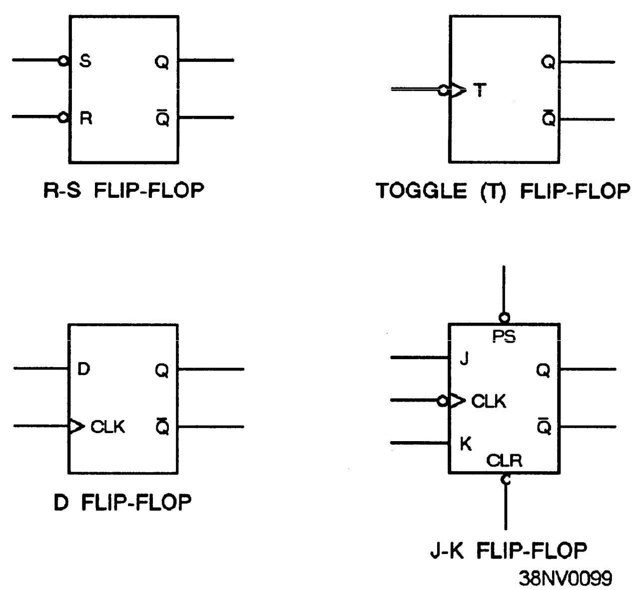


Figure 4-11.—Examples of types of flip-flops.

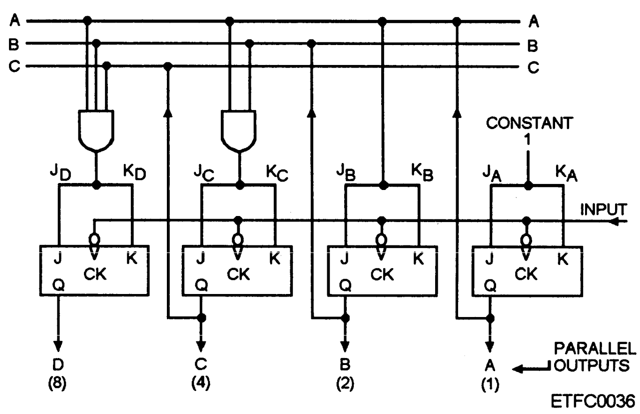


Figure 4-12.—Example of a synchronous operation with a flip-flop.

- T (Toggle) flip-flop —Changes state on command from a common input terminal
- D (Data) flip-flop (latch) —Uses a data input and clock input
- J-K flip-flop —May perform the function of an R-S, T, or D flip-flop (the most versatile)

FLIP-FLOP OPERATIONS.— Some of the operations associated with flip-flops are as follows:

- Synchronous operations —This term describes the operation of logic functions that are controlled by the occurrence of a specific timing signal. Usually the timing signal is the computer's timing signal and is commonly referred to as the clock pulse. See figure 4-12.

- Asynchronous operations —This term describes the operation of logic functions that are **not** controlled by the occurrence of a specific timing pulse. Refer to figure 4-13.

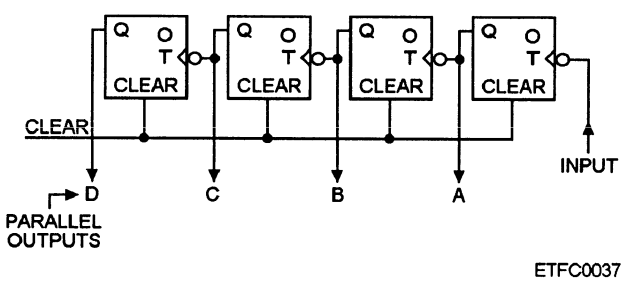


Figure 4-13.—Example of an asynchronous operation with a flip-flop.

- Gated (latched) operations —This term is used when describing logic functions that can be **turned on** or **turned off,** dependent upon an input control signal (command or enable). See figure 4-14.

FUNCTIONAL USES OF DIGITAL IC'S

We can divide the functional uses of digital ICs into two distinct areas. There are those IC circuits that **make decisions** based on their inputs, and there are IC circuits that **hold the data in memory-type circuits.** They are used together to route the data throughout the computer. Let's begin with the decision-making functions.

Decision-Making Functions

Decision-making functions consist mainly of combinational gates. For every combination of bits in the various input wires, there is a definite, prearranged combination in the output wires to be decided upon. The output combination is the same every time a particular input combination occurs. Gates are grouped together in various combinations to form the decision-making circuits. Decision-making functions in the computer can be separated into two distinct classes—code converter circuits and data routing circuits.

CODE CONVERTER CIRCUITS.— Code converter circuits are capable of **encoding** data to a usable form for the computer and **decoding** the data so it can be displayed or used by a peripheral. An example of encoding and decoding on a microcomputer is given

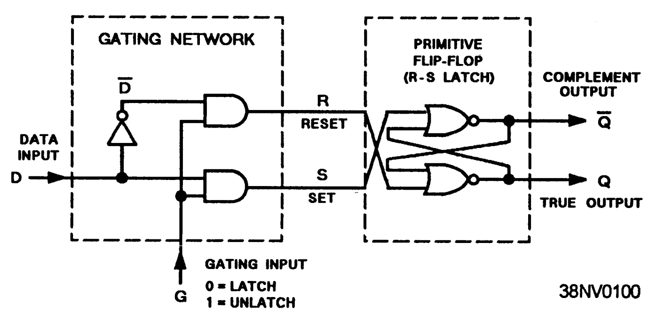


Figure 4-14.—Example of a gated operation.

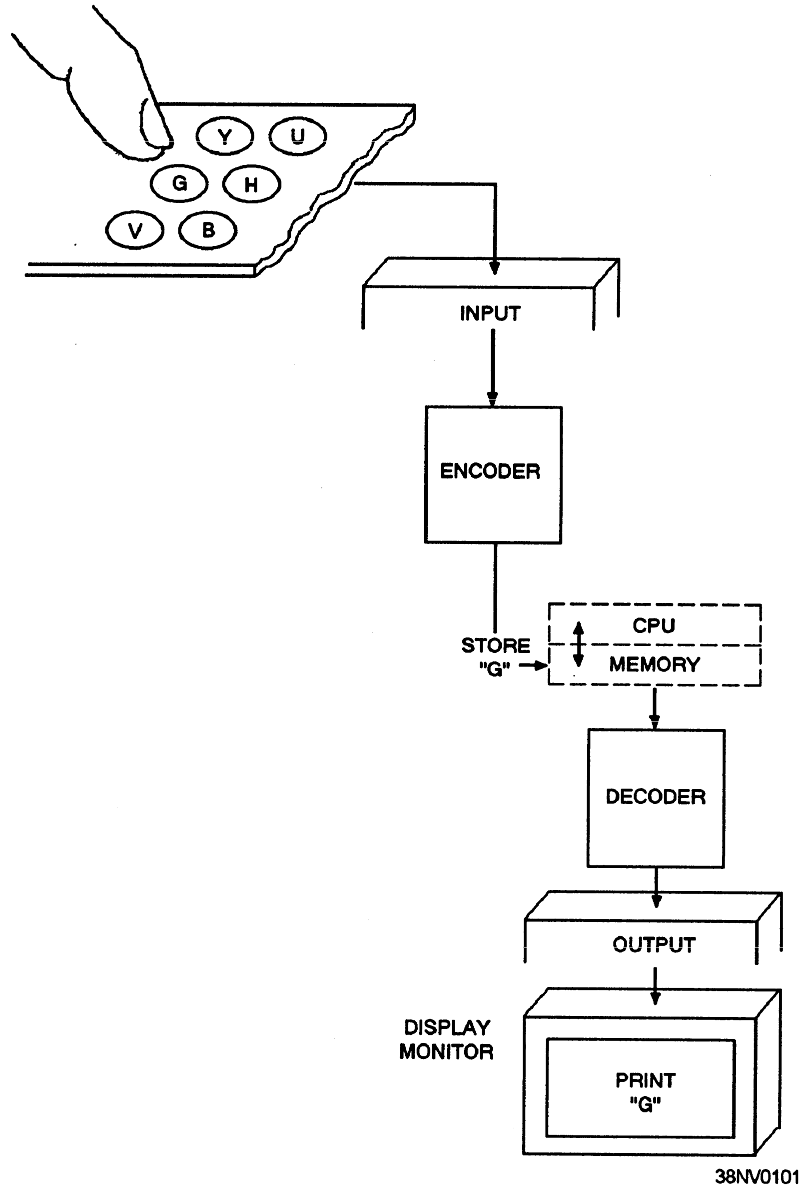


Figure 4-15.—Example of a code converter process to encode and decode data.

in figure 4-15. When you depress the "G" on the keyboard, it is encoded, processed, and decoded so a "G" is displayed on the computer's monitor.

DATA ROUTING CIRCUITS.— Data routing circuits actually route data (the information being processed) inside the computer from various sources to various destinations. Examples in a computer include adders and subtracters, command signals (enables), comparators, demultiplexers, selectors, and translators. A few of the uses areas follows:

- Adder and subtracter circuits —In their simplest form, these circuits are capable of logical (AND, OR, NOT) operations, addition, and subtraction. Multiplication, division, and square root and the more complicated calculations, such as hyperbolic and trigonometric functions, require additional support circuitry such as shift registers and holding registers.

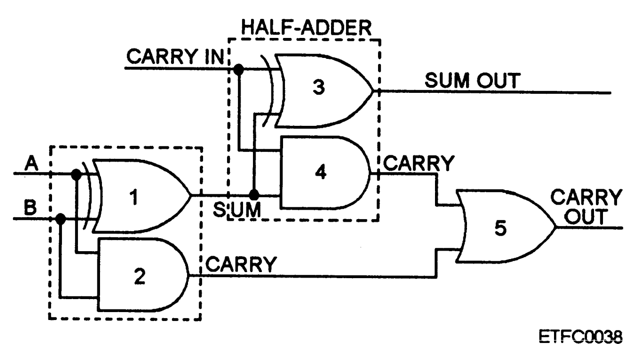


Figure 4-16.—Example of a full-adder circuit.

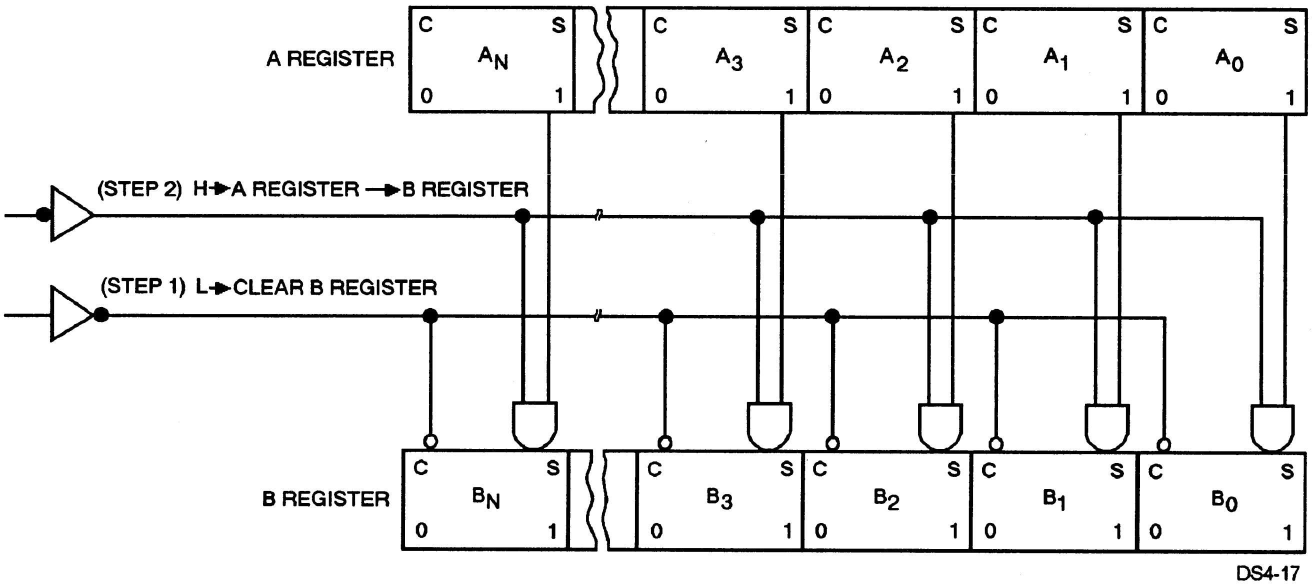


Figure 4-17.—Example of command enable used in a circuit.

Adders and subtracter circuits can be serial or parallel. See figure 4-16 for an example of a full-adder circuit.

• <u>Command signals (enables)</u> —These circuits provide the enable to route information from one destination to another, such as transferring the contents of one register to another. Other examples are to set a condition, start a timing chain, or select an address. See figure 4-17. A closer look indicates that the only time a set side of the B register will be a 1 is when a set side of the A register is set **and** the A register → B register command is enabled (H).

• <u>Comparator</u> —Comparator circuits can be used to compare incoming binary numbers after mathematical operations have been performed on them; for example, to check if two numbers are equal and so on. They can also perform any of several logic gating operations on bits of two binary bits coming in, such as AND and OR operations. In addition, they perform a wider range of comparison operations, such as less-than-or-not and equals-or-not, and these comparisons can be applied to individual **bits** of two input numbers. Figure 4-18 is an example of a comparator circuit (an arithmetic detection circuit).

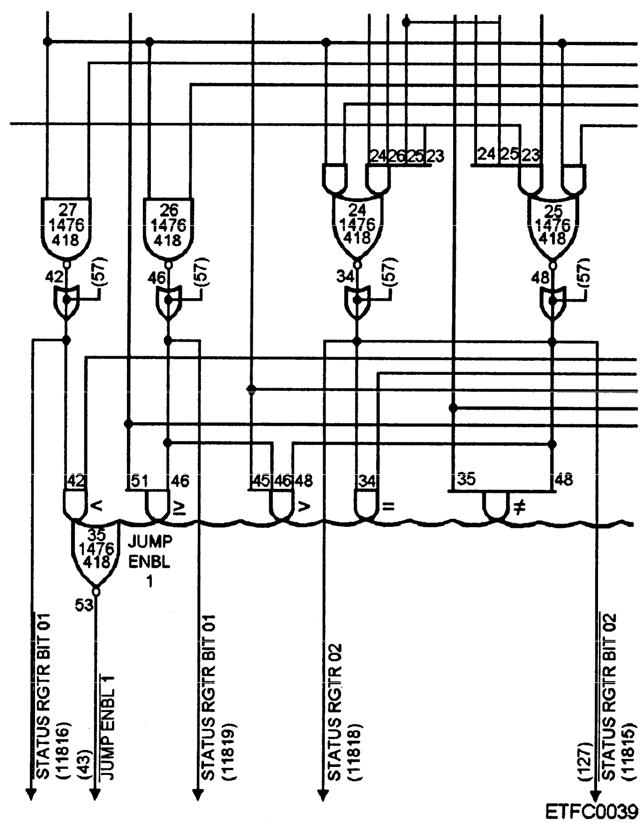


Figure 4-18.—Example of a comparator circuit (an arithmetic detection circuit).

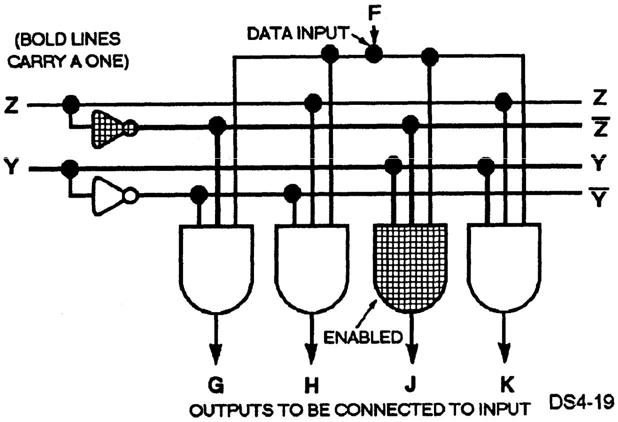


Figure 4-19.—Example of a demultiplexer circuit.

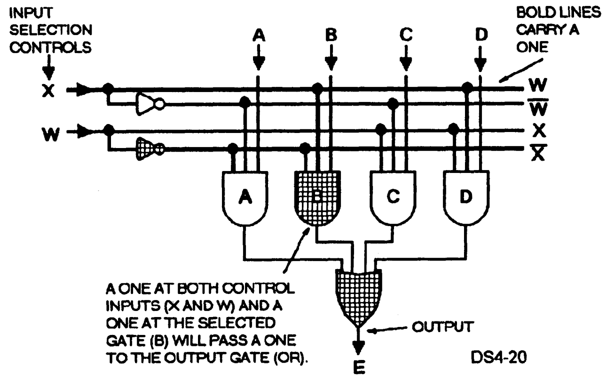


Figure 4-20.—Example of a selector circuit.

• <u>Demultiplexer</u> —A data demultiplexer routes data from one input to any one of several outputs. Refer to figure 4-19.

• <u>Selectors</u> —Some registers have no input selection capability and require the selection of source information to be made before actual input gating. They expand the number of input data paths to a register. Refer to figure 4-20.

• <u>Translators</u> —This type of circuitry in a computer can be used to translate bits of data into a code to be used in different parts of the computer. An example is a function code translator used to translate machine octal codes into function codes so the computer can execute instructions. Different parts of a translator provide partial translation to initiate certain preliminary operations connected with instruction execution. Other parts of a translator provide the

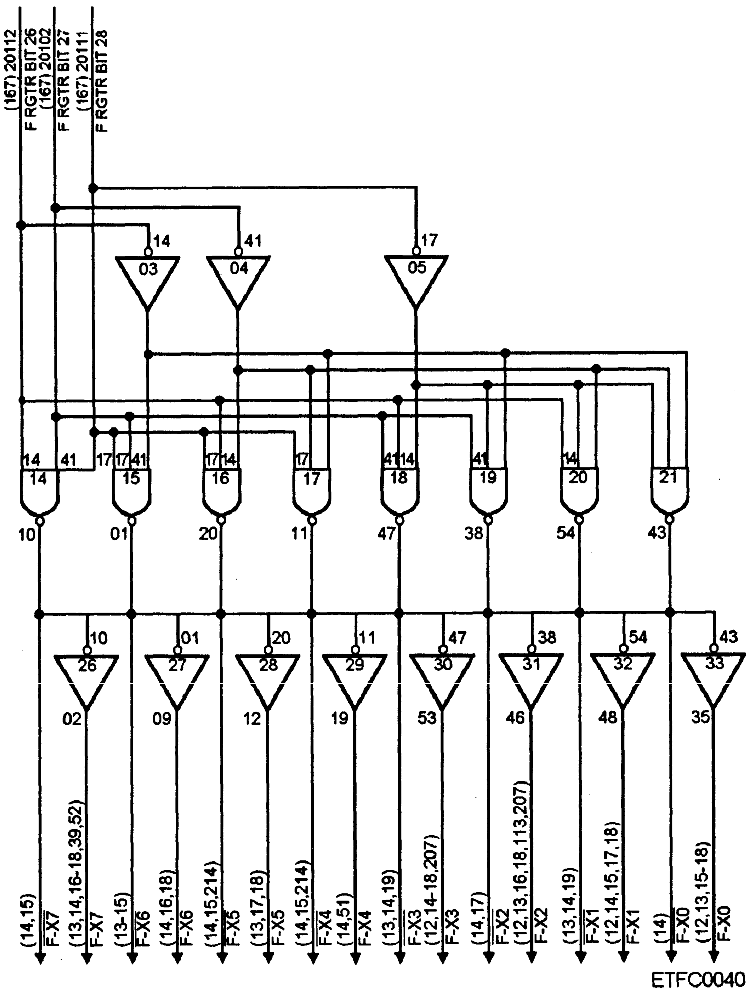


Figure 4-21.—Example of preliminary translator circuitry.

specific code after the code has been through the preliminary circuitry. Figure 4-21 depicts preliminary translator circuitry.

Memory-Type Functions

Memory-type circuits can store information derived from previous combinations of inputs. So the combination of output bits depends not only on the input signals at the moment, but also on previous combinations of bits. These memory-type circuits are called **sequential circuits.** This is because the outputs depend on a sequence, or chain, of inputs at different times. The sequential logic circuits are made up of combinational gates and are commonly called **flip-flops (FFs).** They provide the control and timing in the computer. Let's examine FFs and their uses in computers. The types we cover are counters and registers.

COUNTERS.— Counters are classified by function and circuit design. The function classification refers to how the counter works and is usually the same as the counter name. Counters are used to count operations, quantities, and periods of time; or for addressing information in storage. As an example, the program counter keeps track of where the next instruction is located in memory. Another example is a ring counter, which is used in the computer's timing circuits, where a pulse is output at specific intervals.

The circuit design classification refers to the manner in which the signal being counted affects the flip-flops in the counter. Counters can be designed for serial or parallel operations. If the input signal affects the flip-flops one after another in sequence, it is given the additional classification of asynchronous serial counter. When the signal being counted affects the flip-flops at the same time, it is further classified as a synchronous parallel counter. Whether a counter is asynchronous or synchronous will dictate its use in the circuit.

A counter can be designed to count to any power of 2; or a counter can be designed with a **modulus.** The modulus of a counter is the maximum number of numbers or stable combinations the computer can indicate. You can make a counter with any modulus you need to fit a particular application. For example, a binary counter consisting of five orders or stages will have a modulus of $100000_2 (32_{10})$ since it has the capability of registering and/or indicating all binary numbers from 00000 through 11111.

The three classes of counters (fig. 4-22) are as follows:

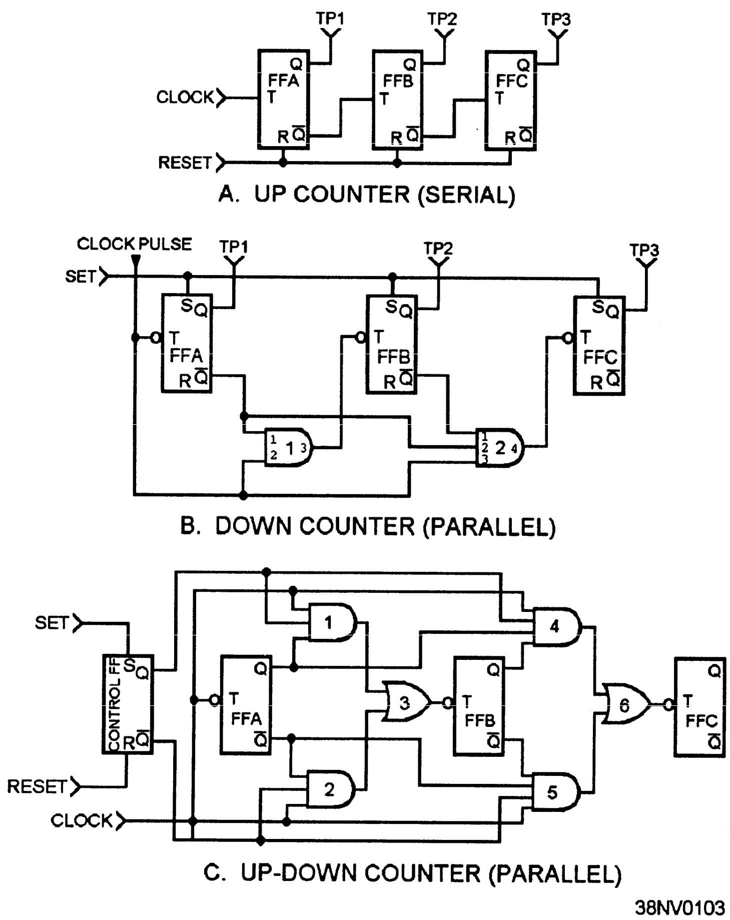


Figure 4-22.—Examples of counters: A. Up counter; B. Down counter; C. Up-down counter.

- Up counter
- Down counter
- Updown counter

REGISTERS.— Registers are built simply by combining groups of flip-flops to act as a unit. The length of a register corresponds to the number of bits or flip-flops within this grouping. Three aspects of registers must be considered. A register must be able to:

- Receive information from one or more sources
- Preserve the information without alteration until it is needed
- Deliver the information to one or more destinations when it is required (command or enable)

Registers can represent one bit or more than one bit. Multiple bits can be represented in various sets such as 4, 8, 16, 32, and 64; the maximum is usually the computer's word size. Registers take on different names depending on their functional use in the computer. They are used throughout the computer. You will learn about some of the specific functional names when you study the functional areas of the computer: central processing unit (CPU), memory, and input/output (I/O).

A register has two parts: the **control** and the **actual flip-flops.** The control (enable) portion contains the logic gates (AND, NAND, and the like) and any input signals or control functions that are common to all the flip-flops in the register.

Some registers can be accessed by programmers and/or directly monitored and accessed on some computers by the front panel. The front panel will either have a display of numbers (some converted for an octal, decimal, or hexadecimal display by LEDs). Other front panels simply display the numbers in binary. These binary numbers can be represented in

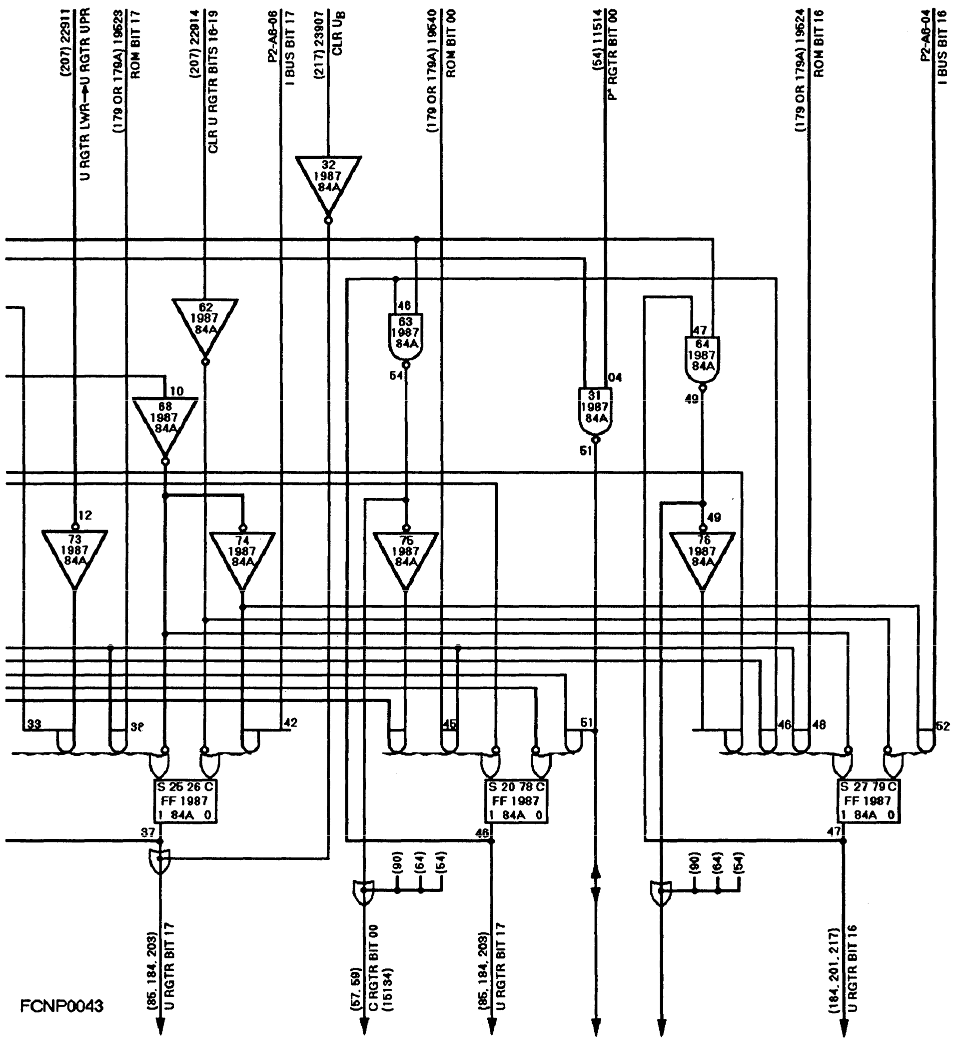


Figure 4-23.—Example of a register.

binary-coded octal (BCO), groups of three LEDs or lamps; binary-coded decimal (BCD), groups of four LEDs or lamps; and binary-coded hexadecimal (BCH), groups of four LEDs or lamps. Through man-machine interfacing, the technician can directly interface with the computer through the direct access of the registers on the computer's front panel.

Let's look at the two types of registers most commonly used throughout the computer—storage and shift registers. Refer to figure 4-23.

Storage Registers.—General storage-type registers do not alter the contents; by this we mean, what enters the register is generally the same as what leaves the register and is received by another register.

The transfer of data to and from a storage register is done in parallel; all the data is transferred at the same time. The methods used to transfer data in storage registers are as follows:

- Single-line parallel transfer (direct method)—Only 1's or 0's are moved in a bit-for-bit, order-for-order method. The receiving register is cleared of its contents before the transfer occurs. If 1's are transferred, it is referred to as a one-side transfer. If 0's are transferred, it is refereed to as a zero-side transfer. See figures 4-24 and 4-25 as examples.

- Double-line (dual) parallel transfer (also called forced method)—1's **and** 0's are moved. This transfer is faster than the single-line parallel transfer; however it requires more logic gates. With this method the receiving register is forced to assume the state of corresponding flip-flops of the sending register. This eliminates the need to clear the receiving register's contents before the transfer. Refer to figure 4-26.

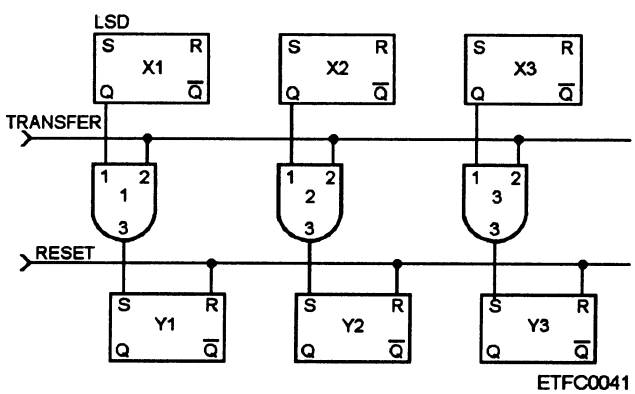


Figure 4-24.—example of a single-line parallel one-side transfer.

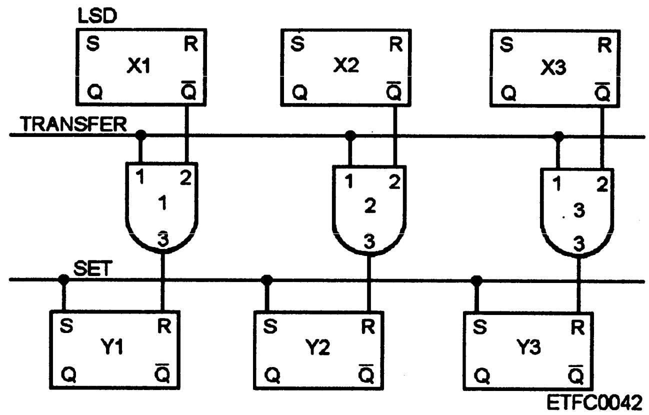


Figure 4-25.—Example of a single-line parallel zero-side transfer.

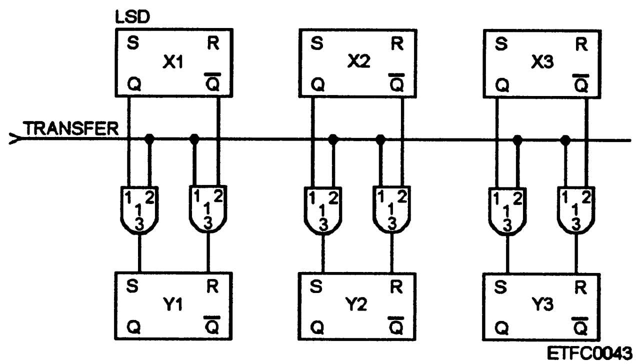


Figure 4-26.—example of a double-line parallel transfer,

- Complement —Similar to the single-line parallel transfer except that the receiving register's set side of the flip-flops will receive the clear side of the sending register's flip-flops; thus the data has been complemented after the transfer is complete. Refer to figure 4-27.

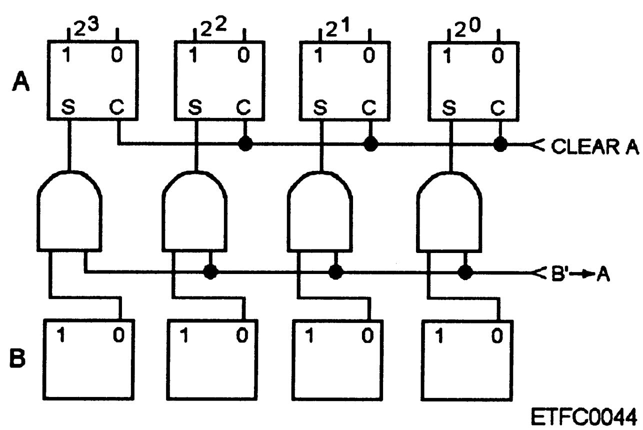


Figure 4-27.—Example of a single-line parallel complement transfer.

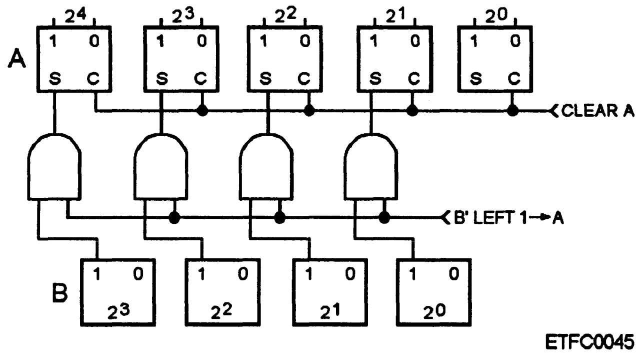


Figure 4-28.—Example of a single-line parallel displaced transfer.

• Displaced —Displaced is also similar to the single-line parallel transfer except the set side outputs of the sending register are gated to the set side inputs of the receiving register one or more orders to the right or left. Refer to figure 4-28 as an example of a displaced transfer.

Shift Registers.—A shift register has the ability to store information the same as the storage register; however it is designed to do more than just store information. A shift register is even more versatile than a storage register. The shift register is capable of receiving, rearranging, and retaining binary data that can be extracted for later use in the computer. It can receive information either in serial or parallel form, and information may be extracted in either serial or parallel form. When the information is extracted in serial form, it may be shifted to the right or left. The shifting is useful in many operations, such as multiplication, division, comparing binary bits, and sequencing a series of events. Remember, shift registers handle both serial and parallel information. Specifically, information can be moved in the following ways:

- Serial in-serial out **right** shift
- Serial in-parallel out **left** shift
- Parallel in-serial out **left** shift
- Parallel in-serial out **right** shift

Figure 4-29 shows an example of a serial in-serial out right Shift.

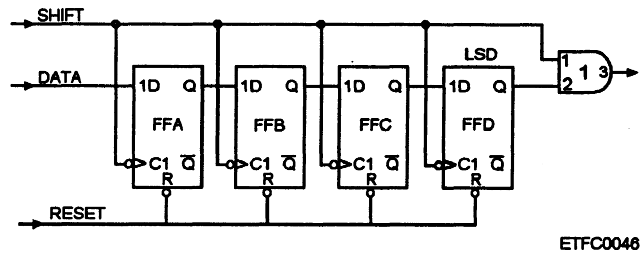


Figure 4-29.—Example of a serial in-serial out right shift register.

TOPIC 5—LINEAR IC'S

Linear circuits are amplifying-type circuits in integrated form. The term *linear* is simply another way of expressing the concept of **regulating** as opposed to **switching,** found in digital ICs. The output of a linear circuit changes in a smooth, even manner as the input is changed at a constant rate, so that a graph of output versus input is approximately a straight line; hence, the name *linear*. In contrast, the output of digital ICs jumps suddenly from one level to another.

LINEAR IC FAMILY TYPES

Linear ICs use **bipolar** and/or **MOS** technology. Among the different types of linear ICs you may encounter are the following:

- Bipolar
- BIFET—A combination of bipolar and junction field-effect transistor (JFET) technology

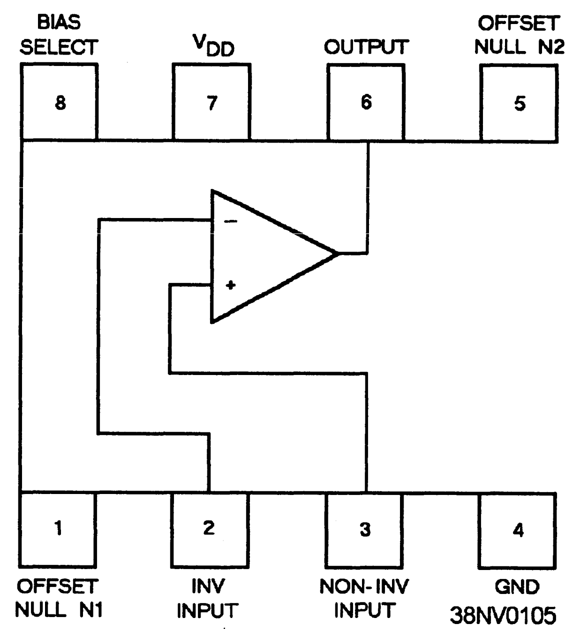


Figure 4-30.—Example of a Lin CMOS—Silicon gate MOSFET.

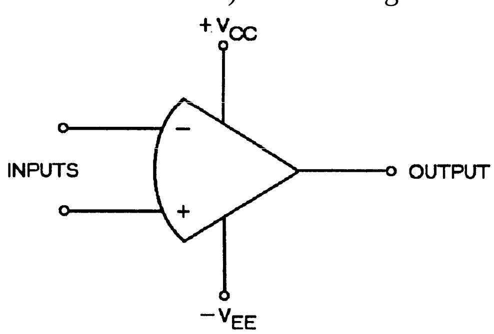
- BIDFET—High voltage bipolar field-effect transistor; MOS technology added to the BIFET approach
- N-FET-MOSFET N-channel FETs
- BIDMOS—Diffused metal-oxide semiconductor (DMOS) and bipolar technology
- Lin CMOS—Silicon gate MOSFETs
- Lin CMOS allows for linear and digital logic on the same IC. See figure 4-30.

LINEAR IC GATES

The basic gate for a linear IC is an operational amplifier (op amp). Its basic function is to **increase** the power, current, or voltage applied to its inputs. It is the basis for other amplifiers used in linear ICs. Atypical op amp has three basic characteristics as follows:

- Very high gain
- High input impedance
- Low output impedance

A typical op amp has two inputs called the inverting input (–) and the non inverting input (+). The inverting input provides a 180-degree phase shift at the output. The noninverting input is in phase with the output. Two power-supply terminals are provided. They are usually called V_{cc} (the collector terminal) and V_{ee} (the emitter terminal). This arrangement enables



A. WITH POWER SUPPLY REQUIREMENTS
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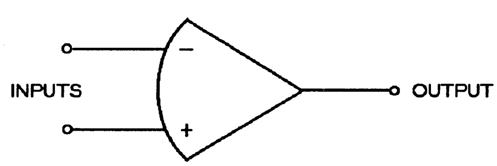

B. WITH ONLY INPUT AND OUTPUT TERMINALS

Figure 4-31.—Example of an op amp: A. Shows power supply requirements; B. Shows only input and output terminals.

the op amp to produce either a positive or negative output. The schematic symbols for an op amp are shown in figure 4-31. View A shows the power supply requirements, while view B shows only the input and output terminals. An op amp can have either a close-looped operation or an open-looped operation depending on its application. Refer to figure 4-32 for an example of a closed-loop op amp.

LINEAR IC GROUPS

The linear ICs contained in a computer can be classified into four groups: analog signal conversion circuits, regulator integrated circuits, driver integrated circuits, and line driver and receiver integrated circuits. The operational amplifier is the key building block in all of these linear ICs because of its ability to amplify without the need for inductors or transformers. Basic variations of the operational amplifier are included in the classification of the four groups of linear circuits.

Analog Signal Conversion Circuits

Analog signal conversion circuits convert an electrical or non-electrical variable to digital. These linear circuits include analog-to-digital (A/D) converters, comparators, memory drivers, sense amplifiers, and timers.

Regulator Integrated Circuits

Regulator integrated circuits provide a constant voltage or current supply. They can accomplish this from a constant or variable power source. Regulator integrated circuits include voltage regulators and switching regulators.

Driver Integrated Circuits

Driver integrated circuits generate large voltage or current output digital signals from small voltage and

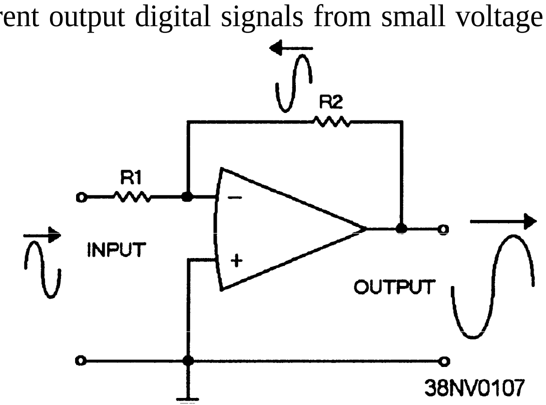

Figure 4-32.—Example of a closed-loop op amp.

current bipolar or MOS digital signals. Driver integrated circuits include peripheral and display drivers used inside an equipment.

Line Driver and Receiver Integrated Circuits

Line driver and receiver integrated circuits are used to transmit digital information from one subsystem or system to another. A line driver is used at the transmitting end and a matching line receivers required at the receiving end. Line drivers and receivers provide a reliable transfer over short and long distances for the high-speed digital signals, which are degraded by noise and attenuation (especially over long distances). They accomplish this by the line driver converting the input digital signals to current pulses in the transmission line (cable). During the course of travel, the current pulses produce very low voltages at the receiver. The receiver detects the signals using high gain and a very low threshold.

FUNCTIONAL USES OF LINEAR IC'S

The functions of linear circuits can be classified into three groups: general linear circuits, systems interface circuits, and consumer-and-communications circuits. The first two types, general linear circuit and system interface circuit functions, are used in the architecture of computers.

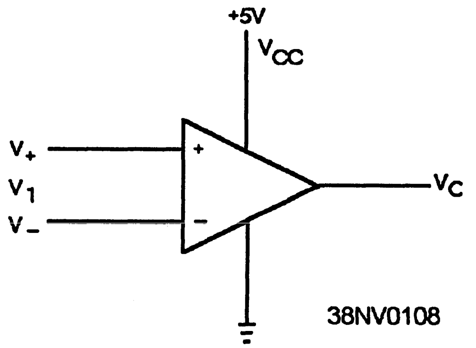

Figure 4-33.—Example of a comparator symbol.

General Linear Circuits

General linear circuits perform the amplifying functions inside the computer. They are used for a variety of functions in the computer's memory, I/O, and power supply. Some of the functions are analog-to-digital converters, comparators, voltage regulators, switching regulators, and timers.

ANALOG-TO-DIGITAL (A/D) CONVERTERS.— These circuits are used to input analog data to digital data so the data can be processed by the computer's digital logic circuits.

COMPARATORS, VOLTAGE REGULATORS, AND SWITCHING REGULATORS.— These circuits are used in power supplies to regulate output power and to detect abnormal input power

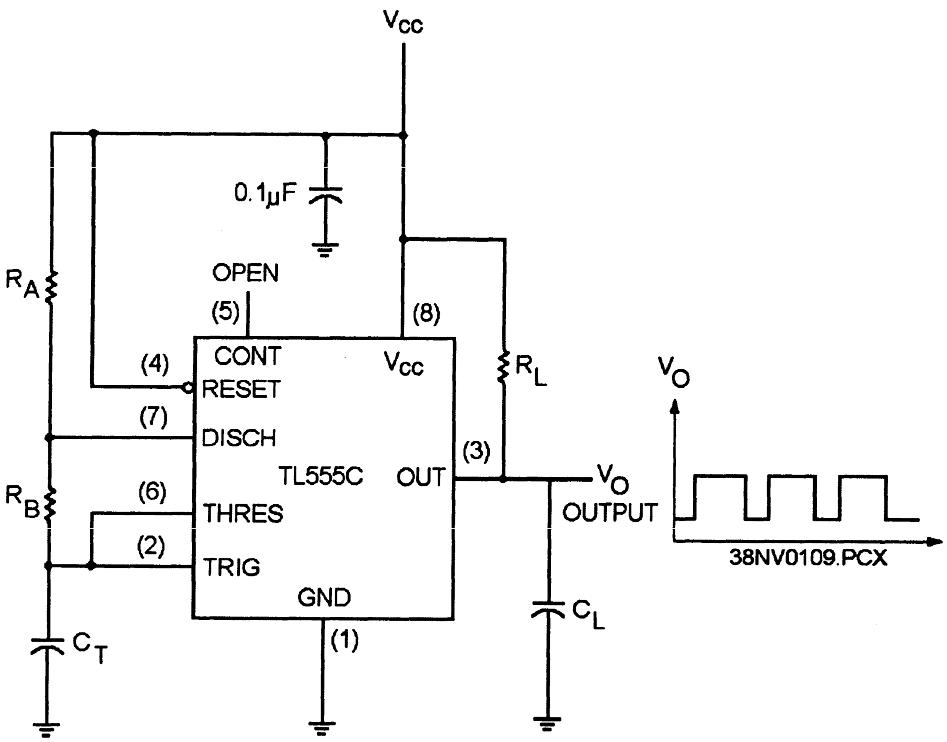

Figure 4-34.—Example of a timer circuit for astable operation.

variations and overtemperature conditions. Protection circuitry to shut down the computer set before component damage occurs is also included. Figure 4-33 shows an example of a comparator symbol.

TIMERS.— Timers use a basic comparator circuit to drive a flip-flop. They can be used to produce a circuit known as an astable multivibrator, which is used to generate digital pulses of known widths and to provide known time delays in digital circuits. These timer circuits are used in the computer's timing and control section. See figure 4-34.

Systems Interface Circuits

Systems interface circuits amplify data signals entering or leaving the computer. They act as a go between, or **interface** that allows the various functional areas or subsystems of a computer system to be coupled together. The systems interface circuits of a computer can be classified into the following areas: memory drivers and sense amplifiers; peripheral and display drivers; and line drivers and receivers.

MEMORY DRIVERS AND SENSE AMPLIFIERS (DC AMPLIFIERS).— These circuits serve as writing and reading units for magnetic memories. Specifically they perform the following:

- Memory drivers —The memory drivers **write** information into magnetic memories.

- Sense amplifiers —The sense amplifiers get the data out. They sense when a core flips from a 0 to a 1 or vice versa. This reduces the chances of interference from stray signal sources.

PERIPHERAL AND DISPLAY DRIVERS.— These drivers are similar to memory and line drivers. They drive digital information in computer, peripheral, and display equipment. They do this by receiving a small voltage and current digital signal(s) from bipolar, MOS, or CMOS logic gate output and generating large voltage or current output digital signal(s). Specifically these circuits perform the following:

- Peripheral drivers —Peripheral drivers receive an input from bipolar or MOS logic gate output and drive the output stage so that relatively large output currents can be controlled with low-level logic signals. Peripheral drivers use a single input and output application. They are very useful for driving indicator lamps or drive relays. See figure 4-35.

- Display drivers —Display drivers use a multiple input and output application. Three types of displays have drive requirements; they are the **ac plasma** display, the **electroluminescent (EL)** display, and the **vacuum fluorescent (VF)** display. Each of the three display drivers requires high voltages but each has unique voltage and current requirements.

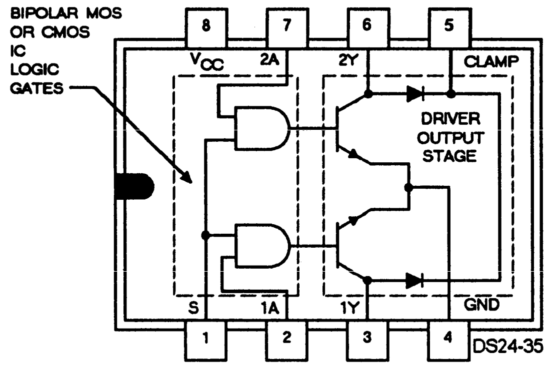

Figure 4-35.—Example of a peripheral driver IC.

LINE DRIVERS AND RECEIVERS. — Line drivers and receivers are used in the transmission of digital signals over both long and short distances. Line drivers are used at the sending end and line receivers are used at the receiving end. They are used in serial and parallel applications for sending and receiving data in I/O operations of the computer. There are two types of line drivers and receivers as follows:

- Single-ended line drivers and receivers — Single-ended line drivers and receivers (fig. 4-36) are used for short distances. They have a single input and output at both the transmitting and receiving end. They are usually wire cables, possibly with an outer shield connected to ground. They are used for local transmission to external equipments (including computers) and for remote communications with modems.

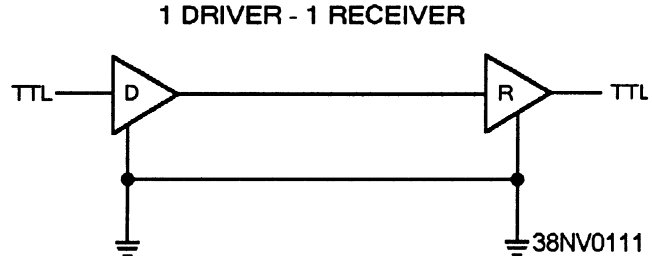

Figure 4-36.—Example of a single-ended line driver and receiver.

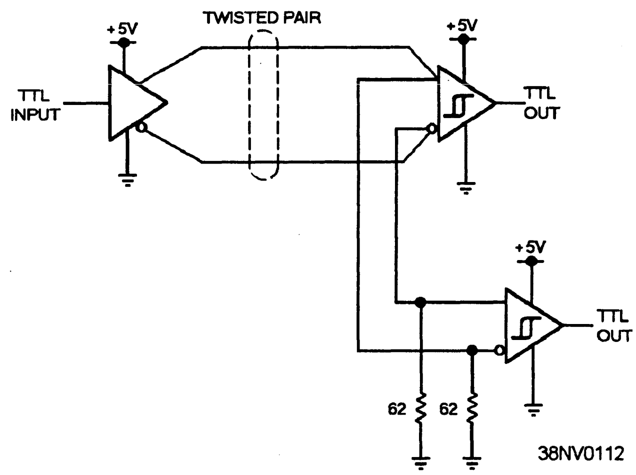

Figure 4-37.—Example of differential point-to-point line drivers and receivers connected in parallel.

- Differential drivers and receivers —Differential drivers and receivers are used over long distances for high-speed communications. They are usually twisted pairs of wires or coaxial cables. Differential types can be point-to-point (fig. 4-37) or multiple source and destination (fig. 4-38).

Single-ended and differential line drivers and receivers are commonly used by some of the following interfaces:

- NTDS Input/Output (MIL-STD 1397)
- RS-232 (EIA RS-232)
- RS-422 (EIA RS-422)
- RS-449 (EIA RS-449)

Line drivers **drive** digital information over both long and short distances to other equipments in a computer system. Line drivers do this by generating large voltage or current output digital signals from small voltage and current TTL or MOS digital signals to travel over transmission lines.

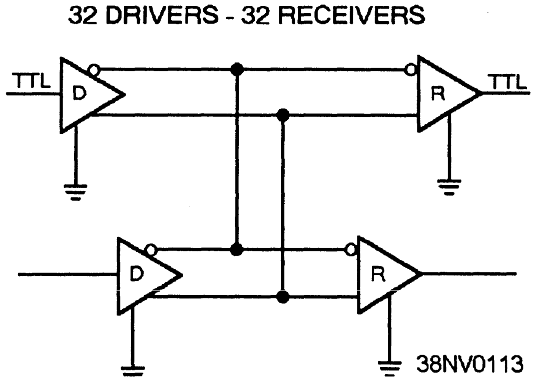

Figure 4-38.—Example of differential multiple source and destination line drivers and receivers.

Line receivers **receive** digital information from both long and short distances from other equipments in a computer system. By the time the data reaches the line receiver from a line driver, the voltages are very low. The receiver operates with a very low threshold to detect these signals. Line receivers are usually used for long distances for parallel transmission.

TOPIC 6—TIMING CIRCUITS

Control and timing circuits comprise a very important area of a computer. A computer's operations rely on commands/instructions being controlled (enabled and disabled) at specific times. Timing circuits are used to ensure the proper timing of enables and disables throughout the computer. Timing pulses are used to enable and disable specific circuits. This permits specific operations to begin and others to be ended. The return of these pulses a short time later could cause an enabled circuit to be disabled and another circuit to be enabled. In this way, operations previously begun are ended and anew set of operations is started.

When a program is installed and operating, circuits are enabled and disabled through a sequential process that continues until one of the following events occurs:

- The program is completed
- A programmed stop is reached
- A fault condition occurs

A pulse generator of a type determined by computer design provides the main timing signals for any given type of computer. These pulse generators are commonly termed master clocks or reference generators. They usually operate at a frequency or pulse repetition rate determined by the maximum rate at which the computer handles data. The **master clock** is the key to the timing circuits in the computer. It will set in motion the computer's main timing circuits. From the main timing circuits, other timing circuits for the various other areas (arithmetic, memory, and I/O) can be enabled or disabled. The clock will produce electrical pulses with extreme regularity. The speed of the computer's clock is determined by an oscillator.

TIMING CIRCUIT COMPONENTS

Timing circuit components consist of wave generators and wave shapers. In computers, waveforms must be turned on and off for specific lengths of time. The time intervals vary from tenths of microseconds to several thousand microseconds. Square and

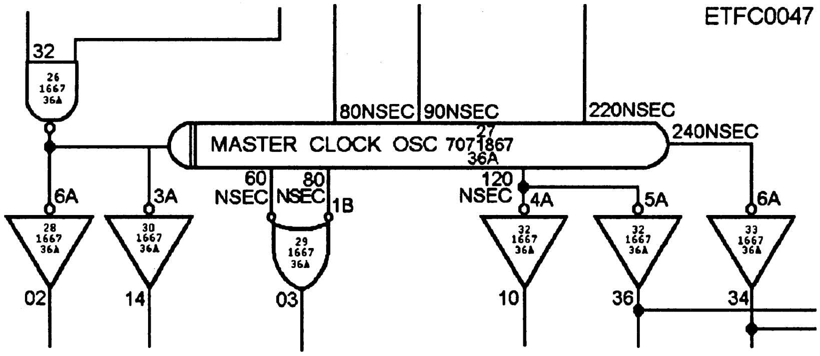

Figure 4-39.—Example of a delay line oscillator.

rectangular waveforms are normally used to turn such circuits on and off because the sharp leading and trailing edges make them ideal for timing purposes. The components used to accomplish this depend on the complexity of the computer. The components you will most frequently encounter in timing circuits are oscillators and multivibrators.

Oscillators

Oscillators are used in computer timing circuits for their output and frequency stability characteristics. The more important quality of the two for use in computers is their frequency stability. The speed of a clock is determined by the oscillator using a resistance-capacitance (RC) or inductance-capacitance (LC) network and/or crystal combination. An oscillator can use bipolar or MOS technology. Crystal-controlled oscillators are used in computers because they are stable even at extremely high frequencies. Master clocks in computers often use an oscillator with a delay line to deliver the basic clock phase and any additional clock phases. See figure 4-39.

Multivibrators

Three types of multivibrators are used in timing circuits. They are astable (free running), bistable (flip-flop), and monostable (one-shot) multivibrators. We have already discussed bistable flip-flops and their uses in a computer. How they are used will depend on the technology of the computer. Generally speaking, when used for timing circuits, we can say:

- Astable (free running) multivibrators provide the voltage pulse to trigger a one-shot multi vibrator.
- Monostable (one-shot) multivibrators shape the pulse to be used to enable and disable circuits, logic gates, and special registers. They can be used in single- or multiple-phase systems.
- Bistable (flip-flops) multivibrators are used as a special register to count clock pulses from a one-shot multivibrator or an oscillator.

TIMING CIRCUIT FUNCTIONS

The uses of astable and monostable multivibrators depend on the complexity of the computer. The multivibrator can be used to provide the pulse and/or pulse shaper. Let's discuss their two types of uses. They are single-phase clock systems and multiple-phase clock systems.

SINGLE-PHASE CLOCK SYSTEMS.— A single-phase clock system consists of a free running multivibrator and a single-shot multivibrator. A free running multivibrator provides the pulse and the single-shot multivibrator shapes the pulse. An oscillator could also be used to provide the trigger pulse for a single-shot multivibrator. The pulse is the output of the pulse shaper, which is then used to enable and disable circuits in whatever sequence is necessary to properly execute the computer program. Refer to figure 4-40 for a simple diagram (block and timing) of a single-phase clock system.

MULTIPLE-PHASE CLOCK SYSTEMS.— A multiple-phase clock system on the other hand provides multiple pulses that can be used to alternately enable and disable circuits. This permits functions involving more than one operation to be completed during a given clock cycle, or a given operation to be extended over more than one clock cycle. A multiple phase clock system can consist of an oscillator or free running flip-flop, and single-shot multivibrator combination, or a delay line oscillator and flip-flop combination. Remember a crystal-controlled oscillator will provide better

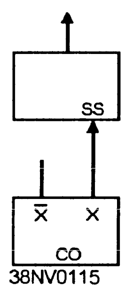

Figure 4-40.—Example of a single-phase clock system.

frequency stability. Figure 4-41 is an example of a timing circuit (block and timing diagram) using an oscillator and flip-flop combination. Notice how with the use of a ring counter (flip-flops), we can generate additional phases that can be used for more complex functions involving multiple operations.

CAUTION

REMEMBER, COMPUTER CIRCUITS CONTAIN ESDS DEVICES. ONLY PERSONNEL WITH ESDS TRAINING SHOULD HANDLE ESDS DEVICES!

TOPIC 7—COMPUTER DATA TYPES AND FORMATS

Different types or kinds of data can be processed by a computer. The types are as follows:

- Bit —The smallest data element or operand is the bit. Individual bits are used primarily in status indicating and flag registers. The two possible states (0 or 1) indicate either ON/OFF, TRUE/FALSE, or other two-state conditions.

Depending on the type of computer, single bits in a memory word can be addressable by a single instruction. Larger computers and some of the newer microcomputers have this capability. Most mainframe computers and some newer microprocessors have machine instructions that allow for single-bit operations (set, clear, or test). If a processor cannot address a single bit, there are software algorithms (small programs) that can combine a number of microinstruction to perform single bit operations.

- Nibble —The next larger data element or operand is the nibble. A nibble is a 4-bit grouping or half-byte of data. Nibbles are used to store a single binary coded decimal (BCD) digit.

- Byte —Probably the most commonly accessed data element is the 8-bit byte. Microcomputer memories can use a single byte, two bytes, or more. Bytes form the basis for operand operations. In addition, each 8-bit byte can store a single alphanumeric character in American National Standard Code for Information Interchange (ASCII) format or another coding system. It can also hold a binary number equivalent to 255_{10}.

- Word —For computers with 16-bit or larger computer words, there are two more data elements. The

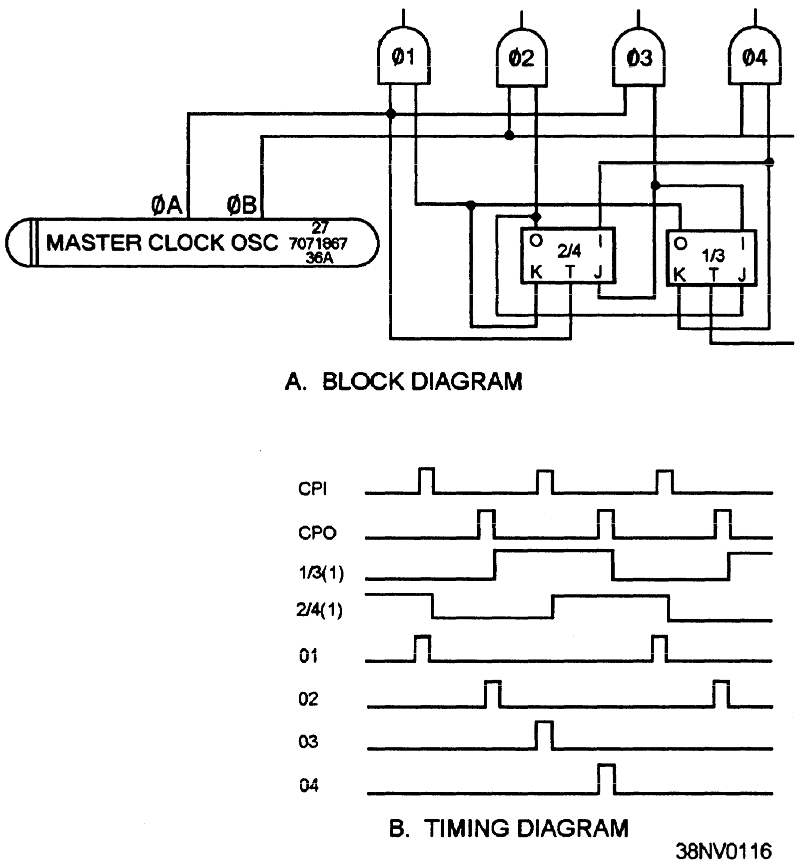

Figure 4-41.—Example of an oscillator and flip-flop combination: A. Block diagram; B. Timing diagram.

first of these is the word or **single word.** A word contains exactly the same number of bits as the computer's registers (16, 30,32, or 64bits). In 16-bit microprocessors with 8-bit memory words, a 16-bit word is assembled from two bytes of memory (fig. 4-42). The word forms the basis for most operand/data operations in 16-bit and larger word size computers.

- Double word —Large numbers are often a problem in digital computers. There are a number of mathematical operations in which the size of the result would be greater than the length of either of the two registers used to provide inputs to the arithmetic logic unit (ALU) or the operands being input to the ALU are larger than a single word. For these situations, double length memory words or double words are often used in computers. A double word is an addressable data element that can be stored in memory (two sequential memory words), or loaded into registers (two sequential registers), and used as an operand for mathematical operations dealing with extremely large numeric values.

TOPIC 8—POWER SUPPLIES

All digital computers have an internal power supply. The power supply in the computer **does not** supply power. It receives ac voltage from a source and **converts** it into useable dc voltage(s). Most computers require multiple dc voltages and levels. The dc is then distributed to where it is needed. The power supply in a computer is a **switching** power supply. This means the power supply can handle quite a range of power supply irregularities with minimal difficulties. It is designed to provide precision voltages, sense irregularities (input and output), and protect the computer from serious damage. Let's see how the computer's power supply accomplishes this; we begin with the operations.

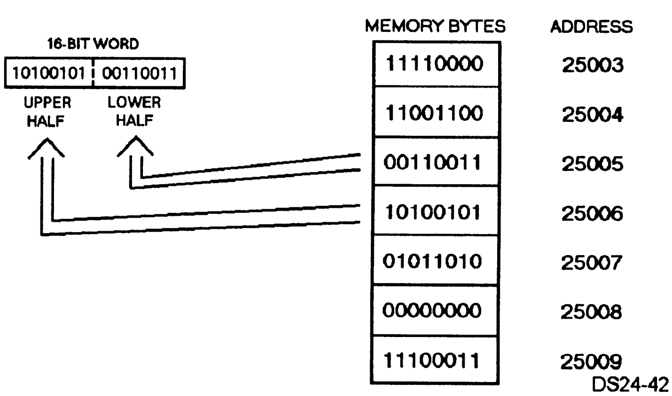

Figure 4-42.—Assembling a 16-bit word from two bytes.

The basic operation of any computer's power supply is accomplished by four basic sections: a **transformer,** a **rectifier,** a **filter,** and a **regulator.** How each computer performs this operation depends on the computer's requirements. Figure 4-43 is a block diagram of a basic power supply. Because of their general makeup, digital computers use power supplies and, in some cases, external devices that allow the power supply to provide precision voltage and **internal** protection. The four basic sections of a power supply make up the foundation used to provide additional circuitry. The computer will receive the precision voltage and protection. For a detailed description of power supply operations in general, consult NEETS, Module 7, *Introduction to Solid-State Devices and Power Supplies.* For a detailed description of your computer's power supply, consult its technical manual.

INPUT

The computer can handle a range of input voltages and frequencies. The computers aboard ship receive their power from a main switch board via a load center(s), a power panel(s), and outlets.

WARNING

SHIPS USE AN UNGROUNDED ELECTRICAL DISTRIBUTION SYSTEM; THEY ARE DEADLY. BE SAFE, KNOW YOUR SOURCE OF POWER.

Computers ashore receive power from a centralized source, and the power is distributed via power panels and outlets. The different ranges depend on the type of computer and/or where the computer is used. These inputs include:

- 440 vac, 60 Hz, 3 phase A
- 115 vac, 60 Hz, 1 phase A
- 115 vac, 60 Hz, 3 phase A

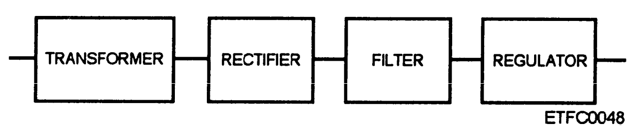

Figure 4-43.—Block diagram of a basic power supply.

- 115 vac, 400 Hz, 3 phase Δ
- 220 vac, 60 Hz, 3 phase Δ
- 115/200 vac, 400 Hz, 4 phase Y
- 230 vac, 50 Hz, 3 phase Δ

Mainframe and minicomputers aboard ship and ashore are preset to receive a specific line voltage. Microcomputers aboard ship use 115 vac, 60 Hz, 3 phase Δ. Microcomputers ashore generally use 115 vac, 60 Hz, 1 phase Δ. However, they have a line select switch located on the back of the micro's chassis to select an alternate line voltage, if needed ashore. In some cases a microcomputer is equipped with a feature that automatically switches over to alternate 220 vac, 50 Hz power. Your ship's electronics doctrine or equivalent document ashore provides the specific voltage and frequency values, as well as the location of power. For reference when dealing with input power, refer to MIL-STD-1399, Section 300A, *Interface Standard for Shipboard Systems, Electrical Power, Alternating Current for Shipboard,* and MIL-HDBK-411, *Power and the Environment for Sensitive DOD Electronic Equipment, Volume I (General), and Volume II (Power),* for ashore.

COMPUTER POWER SUPPLY CONTROLLING DEVICES

Before the input line voltage goes to the transformer section of the primary power supply, it must first go to the computer's man/machine interface, a controlling device. This controls the power supply of the computer, and will vary with the type of computer. Some have an ON/OFF switch at the rear of a computer where blower/fan power and logic power are controlled by one switch. Others have an operator's panel where you can control blower power and logic power separately. Still others have a separate unit where the power is controlled to every major unit in the computer including blower power and the modules in each of the functional areas. You should be thoroughly familiar with the power up and down procedures for your computer. Consult your computer's owner/technical manual and/or electronics doctrine or equivalent.

COMPUTER POWER SUPPLY COMPONENTS

Computer power components include a transformer, a rectifier, a filter, and a regulator.

Transformer

The transformer receives the line voltage from the computer's power controls. This input line voltage is stepped up or stepped down. The transformer isolates the power supply from the input line voltage. Most computers use some means of sampling the input power and/or provide protection before the line voltage is received by the transformer section. Examples are as follows:

- AC line filters —AC line filters eliminate high frequency noise from the input power. They also filter returns from the regulator section.
- Circuit breakers —Circuit breakers protect the transformer when an overcurrent or power fault condition occurs.

Rectifier

The rectifier section converts the ac input signal to a pulsating dc voltage or ripple. This pulsating voltage is not desirable and must be **filtered.** In some computers, this section provides the power necessary for the following:

- System and calendar clock for the computer set
- Display control unit (DCU) interface and power panel control
- Termination resistors for the bus system

Filter

The filter section removes the ripple sent from the rectifier section and produces it into a use able dc voltage. There will still be a small amount of ac ripple on the filtered dc voltage.

Regulator

The final section, the regulator, maintains the output of the power supply at a constant level in spite of large changes in load current or input line voltages. For microcomputers, this is the final section before the power is distributed throughout the computer. For larger computers, the regulator section can provide regulated power to additional circuits where it is further filtered and/or converted. Converters include the following types:

- Regulating converters —Regulating converters provide dc power to the backplane wire harness, and to remote, operator, and maintenance consoles
- Module DC-to-DC converters —Module de-to-de converters provide the required dc

power to the CPU, IOA, IOC, and memory modules

- Secondary power converters —Secondary power converters provide the required de power to the CPU, IOA, IOC, memories, remote operator unit, and display operator unit

OUTPUT

As stated, the rectifier (in some cases) and the regulators distribute the required power throughout the computer. The outputs are used for the following:

- Logic circuits (includes computer's master clock)
- System buses
- Indicators and switches
- Fans (micros)
- Peripherals (micros)

The logic convention and voltage levels vary for each computer type. Consult your owner/technical manual; this is very important when performing maintenance.

COMPUTER POWER SUPPLY PROTECTION

The computer's power supply must protect the computer from the incoming power, the distributed power, and/or the temperature inside the computer's cabinet and/or module(s). Computer protection is the one area where there is a distinct difference between mainframe/minicomputers and microcomputers. We provide general block diagrams to illustrate our point.

Mainframe/Minicomputers

Mainframe and minicomputers are generally equipped with circuitry that will sense the incoming power and monitor power while the computer is up and operating. The incoming power must reach a certain level before the power controlling device will allow you to apply power to the computer and light the appropriate indicators on the power controlling device. The minimum voltage level will vary; consult your computer's technical manual. The regulators of a power supply will generally shut off the computer in the event of uncorrectable power variations.

Figure 4-44 is a basic block diagram that illustrates a power supply for mainframes and minicomputers.

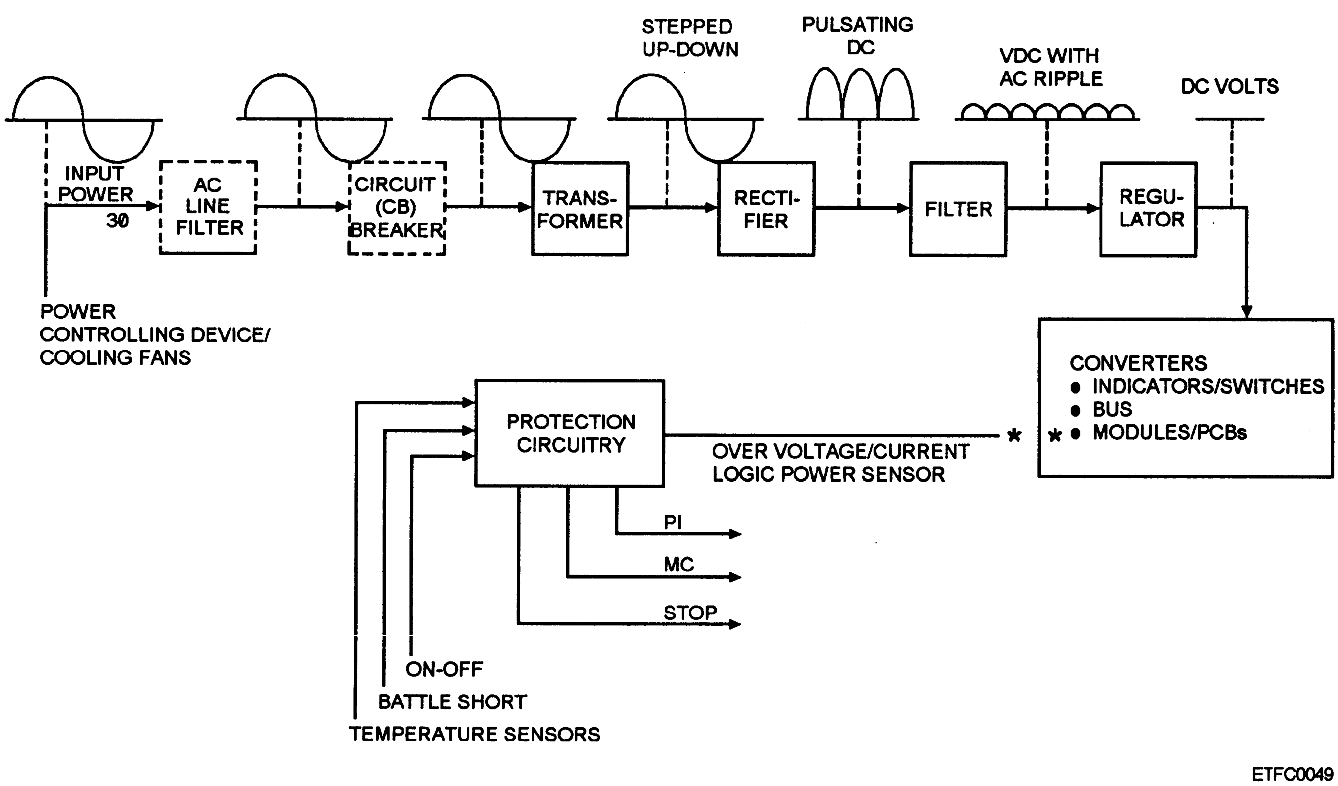

Figure 4-44.—Basic block diagram to illustrate a power supply for mainframes/minicomputers.

A power supply will generally shut off while the computer is running under the following conditions:

- Overtemperature condition (Two overtemperature conditions can occur. A **low** overtemperature condition provides a visual and/or audio warning that can be overridden with **battle short switch.** A **high** overtemperature condition will shut off the power supply.)
- Overvoltage or overcurrent condition

Let's discuss three signals—power interrupt, master clear, and stop. These are the signals a computer can use to provide protection. These signals or their equivalents are used in some computers that also have a pcb dedicated to monitoring power. They monitor ac line voltage to generate signals that allow orderly power start-up and power shutdown sequences. These signals can also be used to provide recoverability.

POWER INTERRUPT (PI).— A PI is generated from the following conditions:

- Source power falls below specifications and returns to normal
- Source power is lost
- Computer set or cabinet is shutoff

A PI will generate a class I power interrupt; this is the highest priority of any CPU interrupt and cannot be locked out except by certain instructions. It alerts the software to a potential power loss. Logic power will remain to parts of the computer for an established time period to allow the software to prepare for the potential power loss. The class I interrupt will give control of the CPU to a subroutine in memory. The subroutine will store certain CPU registers and control memory necessary for program restart. This allows the software to reestablish the conditions that existed before the PI occurred.

MASTER CLEAR (MC), AUTOMATIC.— An automatic master clear signal is generated a specific period after a PI occurs when the logic power falls out of tolerance and when power is lost or the computer set or cabinet is shut off. The MC signal is sent to all parts of the computer and will result in master clearing the CPU, I/O (including disabling acknowledgements in I/O, and main memory). The purpose of the MC signal is for a computer initialization after power has been applied. When the computer power comes to within specifications, the MC will be released and control will go to the auto-restart program if AUTO-START is selected on a controlling panel. Otherwise the computer will be stopped in a cleared condition.

STOP.— A stop signal is generated when the logic power goes out of tolerance. It occurs whether or not a PI signal is present and will send to memory to prevent any new memory references. The purpose of this signal is to prevent the loss of any memory data should logic power be lost faster than a normal turn-off sequence (PI or MC) can occur.

Microcomputers

Microcomputers do not have the temperature requirements that mainframe and minicomputers have. They rely on the temperature of the room they occupy. They can, however, be affected by temperature if they are run when the room temperature is too high; generally above the 80°F mark. We, therefore, concentrate our discussion on the power requirements. Figure 4-45 is a basic block diagram of a microcomputer's power supply. It has the same basic components as mainframes and minicomputers. Microcomputers generate digital active signals out of the final stages to indicate that the power requirements have been met—one for **ac** and one for **dc.**

These signals are provided to the backplane/motherboard. Some computers have power supply LEDS on the backplane/motherboard to monitor the power supply output voltages and the power supply status signals. If a problem exists in the power supply, these LEDs should indicate the problem by remaining off. The ac and dc status signals must be present to reset the computer. If equipped with power supply LEDs, they are used as part of the power-up diagnostic.

AC SIGNAL.— A signal is sent to indicate that the ac input voltage is within specifications. If a minimum of 75 vac is applied to the input for at least 1 second, a signal indicating it has been met goes active. When the input voltage drops to 60 vac or less, the signal goes low and remains low for at least 1 second.

DC SIGNAL.— A signal is sent to indicate that the dc output voltages are within specifications. This signal goes active between 100 ms and 500 ms after the low-to-high transition of the ac signal. The dc signal remains active at least 5 ms (usually the minimum hold-up time for the dc outputs) after the high-to-low transition of the ac signal.

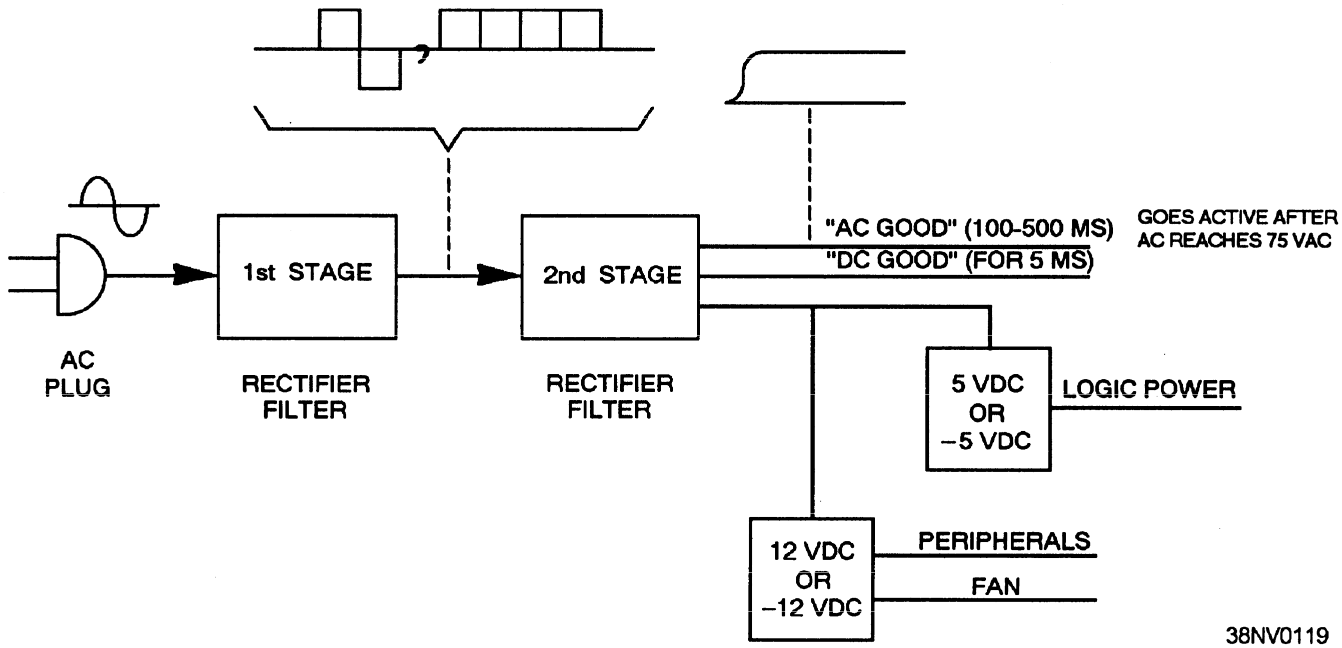

Figure 4-45.—Basic block diagram of a microcomputer's power supply.

EXTERNAL COMPUTER PROTECTION DEVICES

Most computer systems are equipped with some sort of external protective device(s) that may include backup power. They are provided in-line with the input power source. We discuss protection devices and backup power.

Protection Devices

Protection devices are placed in-line with the power source. Compensators are connected to a power panel; compensators and line conditioners use an outlet as their source.

COMPENSATORS.— Electrical compensators provide ac input voltage regulation to ensure reliable operation during voltage changes because of brownouts (where the voltage may dip below the level needed to run the computer) and transient voltage spikes. Electrical compensators do not contain batteries or a power invertor and, therefore, do not regulate or control the frequency of the ac line voltage. Variations in input frequency of the electrical compensator have a direct effect on output voltage regulation.

LINE CONDITIONERS.— Line conditioners filter the input power, bridge brownouts, suppress over-voltage and over-current conditions, and generally act as a buffer between the power source and the computer. It is a real "surge suppressor." The line conditioner is an active device as opposed to a passive surge-protector device. It contains circuits that bridge brownouts or low-voltage situations temporarily.

SURGE PROTECTORS.— These devices are designed to accept voltages as high as 6,000 volts and divert any voltages above 200 to ground. They can accommodate normal surges; but surges, such as a direct lightning strike, blow right through them. These devices can lose their effectiveness with successive surges.

NOTE

APPROVED LINE CONDITIONERS AND SURGE PROTECTORS ARE LIMITED FOR USE ABOARD SHIPS; CHECK NAVY SAFETY REQUIREMENTS FOR USE ABOARD SHIPS.

Backup Power

Backup power devices provide protection to a computer in the event of a complete power loss of the primary power. They provide the time needed for an orderly shutdown or continued operations.

AUTOMATIC BUS TRANSFERS (ABT'S).— ABTs are devices that transfer primary power from one source to another in a minimal amount of time. Some computer power supplies can accommodate this feature. This allows the computer to continue executing software during ABTs or other power absences of up to 100 ms.

STANDBY POWER SUPPLY (SPS).— A standby power supply uses special circuitry that can sense the ac line current. If the sensor detects a power loss on the line, the system quickly switches over to a standby battery and power invertor. The power invertor converts the battery to ac power, which is supplied to the computer.

UNINTERRUPTIBLE POWER SUPPLY (UPS).— An uninterruptible power supply provides power that is completely uninterruptible. It is constructed in much the same way as an SPS with the exception of the switching circuit. Your computer is running off a battery; therefore, no switching takes place and no system disruption takes place. If equipped as such, after a specified time period, a diesel-powered generator is automatically started; this conserves the battery.

SUMMARY—COMPUTER COMPONENTS AND CIRCUITS

This chapter has presented material on computer components and circuits. These include computer number systems, computer logic, and integrated circuits, both digital and linear. It also has presented information on the functions of circuits, the types of data and formats, and the power supplies used by computers. The following information summarizes important points you should have learned:

COMPUTER NUMBER SYSTEMS— Digital computers use derivatives based on binary numbers. The two most commonly used are the octal and the hexadecimal number systems. These number systems are used for functions and mechanization of logic circuits.

INTEGRATED CIRCUITS (ICs)— Computers rely heavily on ICs. An integrated circuit is a complete electronic circuit, containing transistors and perhaps diodes, resistors, capacitors, and other electronic components, along with their interconnecting electrical conductors. The types of integration are small-scale (SSI), medium-scale (MSI), large-scale (LSI), and very large-scale (VLSI). ICs are packaged in many ways.

IC FAMILIES— The IC families are bipolar and metal-oxide semiconductor (MOS). They can both be used in digital and linear ICs. They can also be combined and are called bipolar MOS (BIMOS).

DIGITAL IC'S— Digital ICs handle information by means of switching circuits. They are used to process and store information. The basic building blocks of digital logic circuits contained in a computer are logic gates. The logic circuits contained in digital logic circuits are classified as combinational digital circuits and sequential digital logic circuits.

LOGIC GATES— Three logic gates are the basis for all logic gates. They are the AND, OR, and NOT logic gates. These three logic gates are used indifferent combinations and variations to form logic gates that perform decision-making functions throughout the computer.

FLIP-FLOPS— Flip-flops are sequential logic elements. They have only two output states, either 0 or 1. Flip-flops controlled by a timing signal (commonly called the clock pulse) are called synchronous operations. Flip-flops not controlled by timing are called asynchronous operations. Other flip-flops have gated (latched) operations. This means the logic function is turned on or off dependent upon an input control signal (command or enable).

FUNCTIONAL USES OF DIGITAL IC'S— Digital ICs may be used for decision-making functions. These include code converter circuits and data routing circuits. They are also used for memory-type functions.

LINEAR IC'S— Linear ICs are amplifying-type circuits in integrated form. They are regulating as opposed to switching. The output of a linear circuit changes in a smooth, even manner as the input is changed at a constant rate, so that a graph of output versus input is approximately a straight line; hence the name linear. Linear ICs use bipolar and MOS technology. The basic gate for a linear IC is the operational amplifier (op amp).

FUNCTIONAL USES OF LINEAR IC'S— In computers, linear ICs are used as general linear circuits to perform amplifying functions inside the computer. They are also used as system interface circuits to amplify data signals entering and leaving the computer or internal parts of the computer.

TIMING CIRCUITS— Timing circuits are used in a computer to ensure the proper timing of enables and disables throughout the computers. Timing circuit components consist of wave generators and wave shapers. In computers, waveforms must be turned on and off for specific lengths of time.

COMPUTER DATA TYPES AND FORMATS— The smallest data element is the bit. Next comes the nibble, which is four bits. The byte is 8 bits. The word lengths vary depending on the computer and are the same length as the registers used in the computer, usually 16,30,32, or 64 bits. The double word is twice the length of the word.

POWER SUPPLIES— All digital computers have an internal power supply. The power supply in the computer does not supply power. It receives ac voltage from a source and converts it into useable dc voltage(s). Most computers require multiple dc voltages and levels. The dc is then distributed to where it is needed. The power supply in a computer is a switching power supply. This means the power supply can handle quite a range of power supply irregularities with minimal difficulties. Power supplies have four basic sections. They can handle a range of input voltages and frequencies.

COMPUTER POWER SUPPLY PROTECTION— The computer's power supply must protect the computer from the incoming power, the distributed power, and/or temperature inside the computer's cabinet and/or modules. When overtemperature, overvoltage, or overcurrent conditions occur, the power supply will generally shut off.

EXTERNAL COMPUTER PROTECTION DEVICES— Extemal computer protection devices include protection devices and backup power.

Learn all you can about the internal operation of computers and their circuits. You will need this information to test computer circuits—digital and linear, to identify faulty components and circuits, and to remove and replace (or repair) faulty components and circuits.